ENVIRONMENTAL RISK ASSESSMENT FOR THE WESTERN WASTE MANAGEMENT FACILITY

Submitted to:

Ontario Power Generation Inc.

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Prepared by:

Amec Foster Wheeler

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Revision Summary

Rev	Date	Comments
R000	April 2016	Initial issue
R001	October 2016	The following changes have been made in this revision: • The WWMF ERA has been revised as per W-CORR-00531-01207 "Revised Environmental Risk Assessment for the Western Waste Management Facility" to address CNSC's comments on Rev 000. • Table and figure numbers, as well as reference numbers have been updated throughout the document. • A number of references were updated to account for updated information (e.g., web addresses). • Removed duplicate and unused references.

EXECUTIVE SUMMARY

The Western Waste Management Facility (WWMF) licensing process requires that Ontario Power Generation (OPG) makes adequate provision for the protection of the environment and human health and safety ([1], Clause 0.1.2). This requires identification, quantification, characterization, and prevention or mitigation of effects resulting from the operation of the WWMF. To support these requirements, an Environmental Risk Assessment (ERA) has been completed for the current environment of the WWMF.

The baseline ERA was carried out in accordance with the standard "Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills" (CSA N288.6-12) [2]. It builds on previous ERA or ERA-equivalent work completed for the WWMF and includes analysis of additional baseline data collected for the ERA as well as data collected as part of the current environmental monitoring programs.

The objectives of the baseline ERA are as follows:

- Understand the potential risks resulting from the current operations of the WWMF; and,
- Define baseline conditions to support the assessment for future WWMF expansion activities.

The baseline ERA includes a Human Health Risk Assessment (HHRA) and an Ecological Risk Assessment (EcoRA). The results of the HHRA and the EcoRA are summarized below.

<u>Human Health Risk Assessment</u>

The human health risk assessment evaluated the impact on human health of radiological and non-radiological contaminants in different media, as well as a physical stressor (noise) resulting from the operations at the WWMF.

For radiological emissions, individual dose to human receptors as the result of operation of all nuclear facilities at the Bruce nuclear site was less than 5 µSv/y for the period of 2009-2013. This represents approximately 0.5% of the public dose limit. Given that the emissions from the WWMF represent a small fraction of the overall emissions from the Bruce nuclear site, the dose to members of the critical group due to the operation of the WWMF is estimated to be less than 0.2 µSv/y. Therefore, the operation of the WWMF presents no radiological risk to the public[1].

Based on the screening level risk assessment, non-radiological emissions resulting from the operations at the WWMF are compliant with the standards protective of human health (such as Health Canada and Ministry of Environment and Climate Change standards) and therefore no human health effects are likely.

[1] In this report, likely adverse effects are not considered to occur if the Hazard Quotient is less than 1 or less than 0.2 per medium for non-carcinogens, or less than the incremental lifetime cancer risk value of 10^{-6} per medium for carcinogens. Otherwise they are evaluated in more detail.

From the results of the field noise level measurements and modelling results, the noise levels generated due to the operation of the WWMF are compliant with the relevant standards. Therefore, it can be concluded that noise as a physical stressor poses no adverse effects to human health. Other than noise, no other physical stressor is considered for the HHRA, which is consistent with CSA N288.6-12.

Ecological Risk Assessment

The ecological risk assessment evaluated radiological and non-radiological contaminants in different media, as well as physical stressors resulting from the operations at the WWMF.

Ecological receptors present at the WWMF included terrestrial plants and invertebrates (including insects), aquatic plants and invertebrates, fish, herpetofauna, birds, and mammals. In addition, off-site aquatic receptors residing in Lake Huron could potentially come into contact with surface water Contaminants of Potential Concern (COPCs) at the site.

For radiological substances, all radionuclides were considered to be COPCs and the Tier 2 assessment was carried out.

For non-radiological substances, COPCs were identified by comparing the maximum concentration of each contaminant in each medium measured at the site to appropriate guidelines for the protection of ecological receptors. Where appropriate guidelines were not available, upper background concentrations were used as the screening criteria. Those contaminants with maximum concentrations exceeding the guideline values were identified as COPCs and were subjected to a Tier 2 assessment (Section 1.1.1):

Medium	Soil	Surface Water	Sediment
COPC	Dioxins and Furans	Dissolved Chloride (Cl)	Arsenic
	Sodium Adsorption Ratio	Aluminum	Copper
		Cobalt	Manganese
		Copper	Molybdenum
		Iron	Silver
		Phosphorus	Sodium
		Selenium	Strontium
		Sodium	Tungsten
		Strontium	Zinc
		Zinc	

The risk evaluation for ecological receptors identified the following:

- There are no adverse effects due to exposure to radiological contaminants.
- There are no effects from soil and surface water due to exposure to non-radiological contaminants for terrestrial plants and invertebrates, aquatic plants and invertebrates, fish, herpetofauna, and birds and mammals.

- Risks to benthic invertebrates due to exposure to sediment were assessed based on the comparison of sediment chemistry to the Toxicity Reference Values (TRVs) and a qualitative evaluation of benthic invertebrate field data. The conclusions are:
    a) Copper and zinc in the South Railway Ditch (SRD) exceed the sediment TRVs, and there is the potential for low to moderate effects to benthic invertebrates. However, it is difficult to distinguish whether the limited benthic invertebrate community in the drainage ditch, which consists primarily of tolerant or facultative species, is strictly the product of the poor habitat quality the ditch provides or whether elevated metal concentrations are having an effect. It should be noted that the source of copper and zinc is not associated with WWMF operations and that the ability to survive under low oxygen conditions during periods of low flow, or no flow (stagnation) is probably the dominant factor governing the benthic invertebrate community;
    b) In the Wetland, downstream of the SRD, sediment concentrations were below the TRVs and adverse impacts to the benthic invertebrate community are not anticipated in the Wetland;
    c) Although silver in the West Ditch exceeds the sediment TRV, a low potential for effects was identified. It should be noted that the West Ditch is not located within the WWMF and the WWMF is not known to be a source of silver contamination to the West Ditch, therefore silver was not assessed further.
- Physical stressors including noise, bird strikes, and road kill pose no adverse effects to non-human biota.

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1.0 INTRODUCTION

1.1 Background

1.1.1 ERA Framework

An Environmental Risk Assessment (ERA) is a systematic process to assess the risk posed by contaminants and physical stressors in the environment on biological receptors. In June 2012, the Canadian Standards Association (CSA) published the first edition of *Environmental risk assessments at Class I nuclear facilities and uranium mines and mills* (CSA N288.6-12) [2]. It addresses the design, implementation, and management of an environmental risk assessment program that incorporates best practices used in Canada and internationally.

In accordance with CSA N288.6-12 [2], the following tiers of assessment should be conducted for the nuclear facilities, as appropriate:

- Screening level risk assessment (SLRA) — Tier 1. The first tier of assessment is broad in scope and serves to identify potential issues (receptors and stressors) that require further quantitative evaluation at a higher tier. If no such issues are identified, no further assessment is needed.
- Preliminary quantitative risk assessment (PQRA) — Tier 2. The second tier addresses the identified potential issues quantitatively, generally using available site data. If an issue is resolved as being of no concern, it requires no further assessment.
- Detailed quantitative risk assessment (DQRA) — Tier 3. The third tier addresses any issues that are still of concern after the PQRA.

This progression is illustrated at a high level in Figure 1-1. Specifically, the following tasks, as appropriate, should be performed in each tier:

- Tier 1/SLRA: Characterization of the site; selection of contaminants and physical stressors for screening; comparison of the selected contaminants and physical stressors against the screening criteria; selection of receptors and exposure pathways; determination of assessment and measurement endpoints and development of conceptual model; and completion of problem formulation checklist if needed.
- Tier 2/PQRA: Estimation of exposure concentration or dose for receptors at relevant locations for each contaminant of potential concern (COPC) or physical stressors identified in Tier 1; selection of Toxicity Reference Values (TRV) or benchmark values for each receptor and COPC or physical stressors (if possible); calculations of Hazard Quotient (HQ) for each COPC or physical stressor; and calculation of cancer risk for non-radiological carcinogens for human receptors.

- Tier 3/DQRA: Refining exposure assessment and risk characterization to reduce uncertainty based on the additional site data; consideration of any other lines of evidence; and provision of recommendations for further uncertainty reduction, effect monitoring or risk management.

It should be noted that the biological receptors considered in an ERA include humans as well as non-human biota. The risks posed to human receptors can be addressed through a Human Health Risk Assessment (HHRA) and those posed to non-human biota can be addressed through an Ecological Risk Assessment (EcoRA).

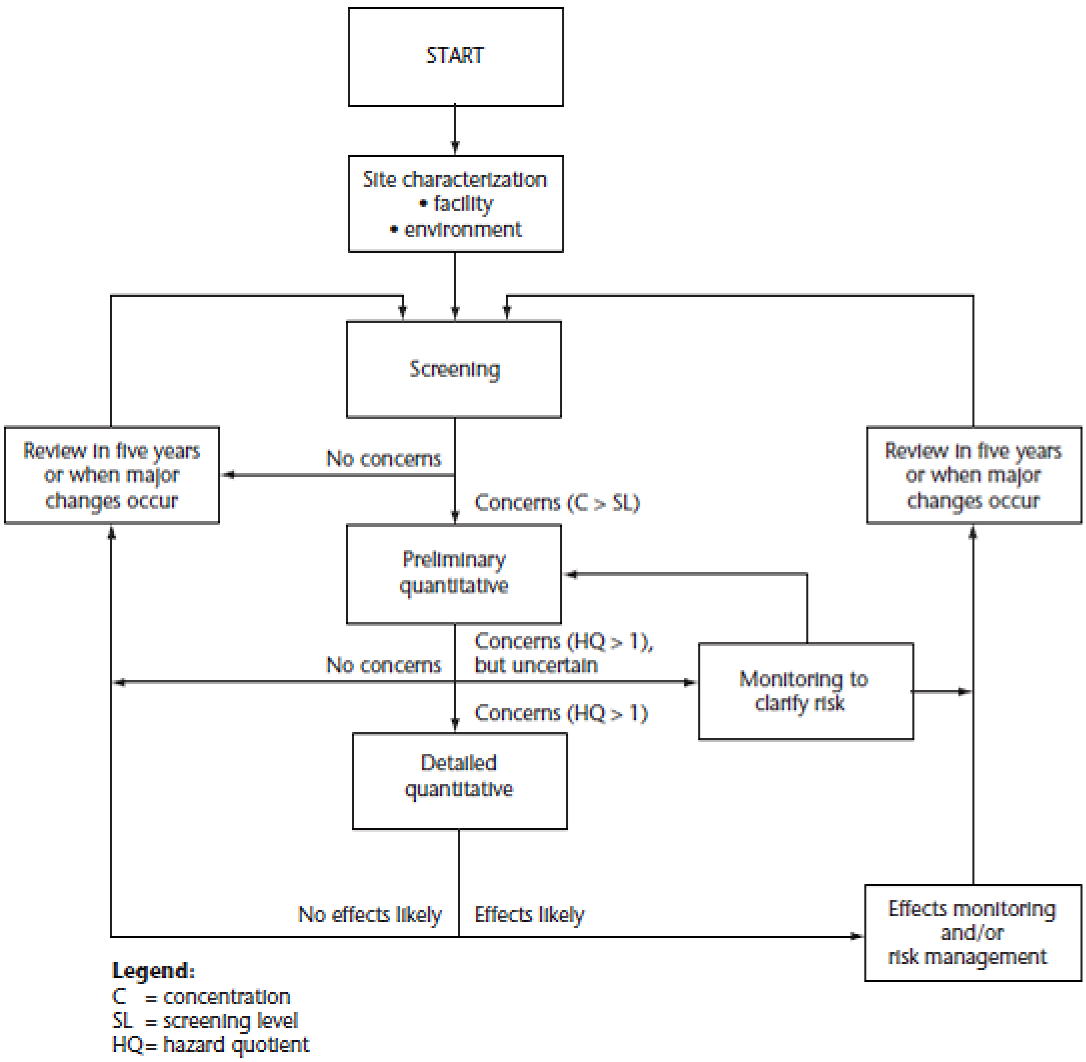

Figure 1-1: ERA Progression through Tiers of Assessment

1.1.2 ERA for WWMF

The Western Waste Management Facility (WWMF) licensing process requires that Ontario Power Generation (OPG) makes adequate provision for the protection of the environment and human health and safety ([1], Clause 0.1.2). This requires identification, quantification, characterization, and prevention or mitigation of effects resulting from the operation of the WWMF. For these reasons, OPG has completed an ERA of the current environment at the WWMF to demonstrate that the environment and human health and safety are protected.

Several ERAs or equivalent assessments have been carried out for the Bruce nuclear site where the WWMF is located. The results of the assessments are provided in the following documents:

- Bruce Nuclear Power Development Ecological Effects Review [3];
- WWMF Integrated EA Follow-Up Ecological Risk Assessment of the WWMF [4];
- OPG Deep Geologic Repository for Low and Intermediate Level Waste EA (DGR EIS) [5];
- WWMF Refurbishment Waste Storage Project EA [6], and;
- Bruce New Nuclear Power Plant Project New Build EA Environmental Impact Statement (EIS) (New Build EA) [7].

These reports have been reviewed. Relevant datasets, including the on-going Environmental Monitoring Program (EMP) and the results, were considered to understand what data are available and whether the data are current to meet the objectives listed in Section 1.2. To this end, a sampling monitoring program was developed to provide a comprehensive characterization of the current environment and is further described in Section 2.2.9.2.

1.2 Objectives and Scope

The objectives of the ERA for the existing baseline environment (hereinafter referred to as the "baseline ERA") are as follows:

- Understand the potential risks resulting from the current operations of the WWMF, and;
- Provide a suitable baseline for future WWMF expansion activities.

The scope of the baseline ERA consists of both the HHRA and the EcoRA for the WWMF.

1.3 Organization of Report

The ERA is carried out consistent with CSA N288.6-12 [2]. The report is structured as follows:

- Section 2.0: Site Description;
- Section 3.0: Human Health Risk Assessment;
- Section 4.0: Ecological Risk Assessment;

- Section 5.0: Conclusions and Recommendations;
- Section 6.0: Quality Assurance; and,
- Section 7.0: References.

2.0 SITE DESCRIPTION

2.1 Site Facilities

The Bruce nuclear site is located on the east shore of Lake Huron, approximately 18km north of Kincardine and 17 km southwest of Port Elgin, in the Province of Ontario, Canada (Figure 2-1). The site occupies an area of 932 hectares (2300 acres) and hosts the WWMF and other facilities (Figure 2-2). The description of these facilities is provided below.

2.1.1 WWMF and Other OPG Operated Facilities

The WWMF covers an area of 19 Ha within the OPG-retained lands. It is a Class 1B nuclear facility[2] for the storage and management of Low & Intermediate Level Waste (L&ILW) and used fuel.

The WWMF facilities currently consist of the L&ILW Management Area, and the Used Fuel Management Area[3]. The layout of the existing waste management facilities at the WWMF are shown in Figure 2-3.

The L&ILW Management Area is enclosed by a fence. The area consists of various structures primarily used for storage and processing of L&ILW from Pickering Nuclear Generating Station (NGS), Darlington NGS and Bruce Power's NGSs. These facilities are as follows:

- Low-Level Storage Buildings (LLSBs #1 to 14): The LLSBs are warehouse-like buildings. The LLSB structural design utilizes prefabricated, pre-stressed concrete. Shielding is provided as required to limit radiation fields. LLSBs provide storage for Type 1 and Type 2[4] Low Level Wastes (LLWs), which consist of items such as mop heads, rags, paper towels, floor sweepings and protective clothing that are minimally contaminated with radioactive material. The LLWs are placed in varying types of containers that are stacked in the LLSBs.

- Steam Generator Storage Building (SGSB #1): The SGSB structural design utilizes prefabricated, pre-stressed concrete. Shielding is provided as required to limit radiation fields. The SGSBs provides storage space for 24 steam generators.

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[2] Class IB is defined in the Class I Nuclear Facilities Regulations, SOR/2000-204, Nuclear Safety and Control Act [8]. The WWMF is classified as 1B as it is a facility for the disposal of a nuclear substance generated at another nuclear facility.
[3] There are seven additional L&ILW storage buildings and additional in-ground storage containers which have previously received Environmental Assessment approval [6] but have not been built.
[4] Type 1 solid wastes are those with a contact dose rate less than or equal to 2 mSv/h. Type 2 solid wastes are those with a contact dose rate less than or equal to 0.15 Sv/h but greater than 2 mSv/h. Type 3 solid wastes are those with a contact dose rate greater than 0.15 Sv/h. Note that the dose rates refer to the state before any volume reduction is performed.

- Retube Component Storage Building (RCSB #1): The RCSB structural design utilizes prefabricated, pre-stressed concrete. It provides storage capacity for retube component waste containers from the refurbishment of reactor units. Additional suitably packaged L&ILW from reactor refurbishment or operation may also be stored in the building.
- Waste Volume Reduction Building (WVRB): The WVRB provides for the management of LLWs, such as waste receiving and handling, compaction, and incineration prior to storage. The WVRB houses an incinerator unit and a compactor unit designed for processing LLWs. The WVRB also incorporates a truck unloading area, electrical and control rooms, and other service areas that support the waste processing function of the facility.
- Transportation Package Maintenance Building (TPMB): The TPMB houses a main shop area for the maintenance and decontamination of transportation packaging used for the transfer of radioactive materials between generating stations and waste management sites. The building also houses an active ventilation room, a smaller machine shop to service equipment for other portions of the WWMF, a control maintenance shop with workstation areas for managing ongoing maintenance work, as well as a mechanical/electrical room, test room, vestibule, and washroom.
- Quadricells[5], In-ground Containers (ICs), trenches, and tile holes: These structures were built to store a variety of solid radioactive wastes. For example, above-ground quadricells provide storage capacity for bulk resin and reactor core components; in-ground trenches provide storage capacity for Type 1 and 2 radioactive wastes. Tile holes, which are vertical and cylindrical below-ground storage structures, are an early design for the storage of Type 3 wastes. They can be used for any wastes with dimensions compatible with tile holes. The ICs provide storage capacity for Type 2 and Type 3 radioactive wastes. Specifically, In-ground Container for Heat Exchangers (IC-HXs) provide storage for waste heat exchangers.

Within the L&ILW Management Area, there is also an Amenities Building. This building provides entry space, office space, locker and shower facilities, and lunchroom facilities for the WWMF staff.

The used fuel management area has additional security protection and is located northeast of the L&ILW storage area. It currently consists of the Dry Storage Containers (DSCs) processing building and four Used Fuel Dry Storage Buildings where used fuel is stored. The DSC processing building provides a facility for the receipt, inspection, preparation for use of empty DSCs, seal welding of loaded DSCs, and office space for personnel. Each DSC storage building is designed to house a maximum of 500 DSCs.

[5] Quadricells: Above-ground facilities with reinforced concrete modules consisting of two independent envelopes with a monitored interspace, designed to hold Type 3 wastes, including resins from storage tanks and reactor core components.

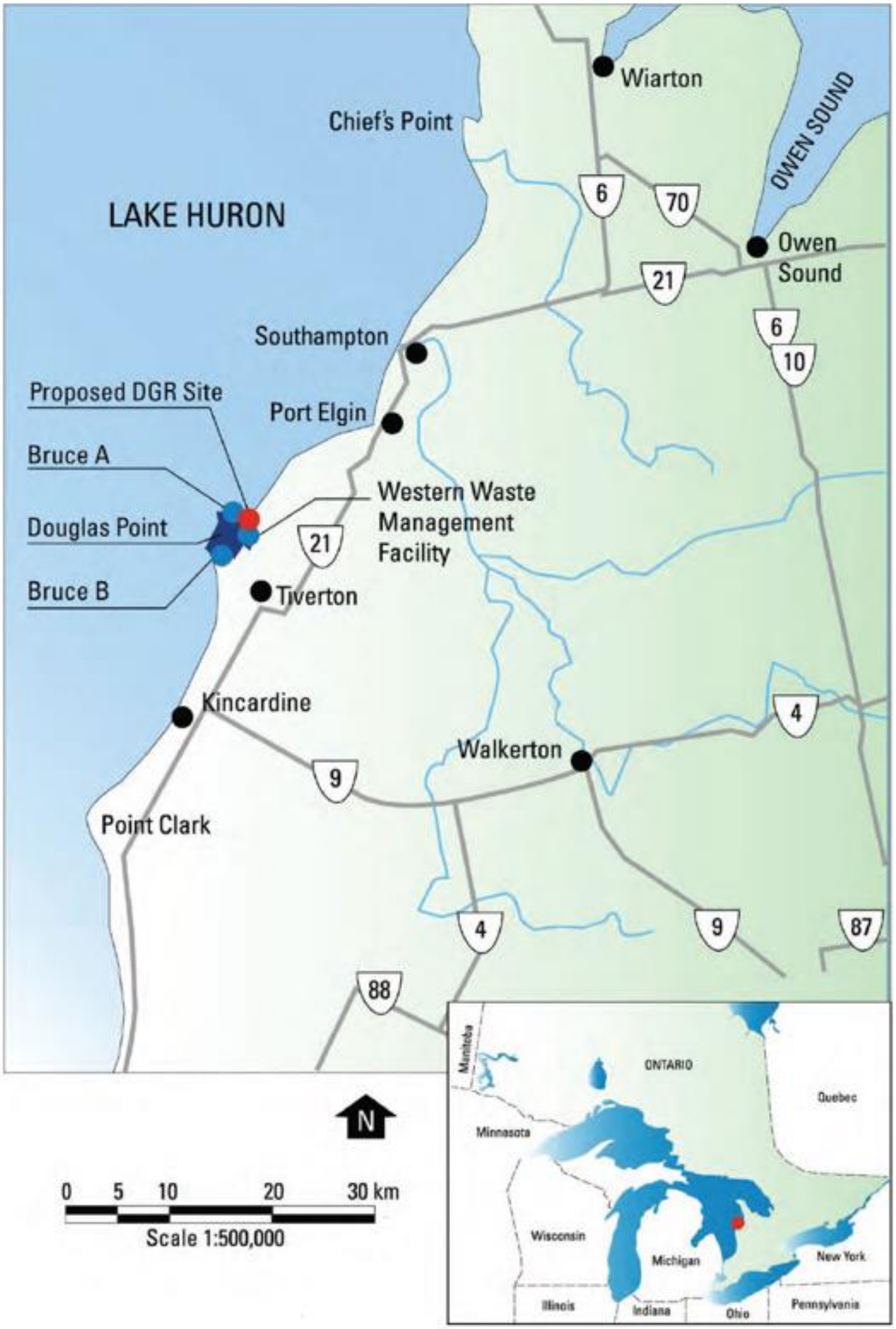

Figure 2-1: The Bruce Nuclear Site [9]

Figure 2-2: Facilities at the Bruce Nuclear Site[6,7] [5]

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[6] Note: AECL is now Canadian Nuclear Laboratories.

[7] The boundaries of the OPG retained land have changed. The land surrounding the Bruce Heavy Water Plant (shown in green, to the northwest of Interconnecting Road) is no longer included in the OPG retained land.

1. LLSBs
2. In-ground Storage (trenches, tile holes, ICs, In-ground container for heat exchangers (ICHXs))
3. SGSB (3-1) and RCSB (3-2)
4. Used Fuel Processing Building (4-1) and Used Fuel Dry Storage Buildings (4-2)
5. Waste Volume Reduction Building and Amenities Buildings
6. Transportation Package Maintenance Building
7. Quadricells

Figure 2-3: Layout of the Existing Waste Management Facilities at WWMF

It is likely that the WWMF will be expanded to accommodate additional buildings for the storage of used fuel, L&ILW and for waste processing. The proposed expansion areas are shown in Figure 2-4. The area outlined in blue was not considered as part of the Project Study Area by previous EAs, but was included in their Site or Local Study Areas, and has been included as part of this baseline ERA. The area outlined in red was previously considered as part of the Project Study Area in the WWMF RWS EA [6] or the DGR EA [5].

In the vicinity of the WWMF, there is one conventional landfill, four legacy construction landfills, and some other facilities as described below, which are also owned by OPG:

- Bruce heavy water plant: The Bruce heavy water plant was in operation from 1973 to 1998 for the purpose of producing reactor-grade heavy water. The heavy water plant has been decommissioned, including the demolition of all above-ground structures, except for concrete floor slabs and foundations which remained in place. The Canadian Nuclear Safety Commission (CNSC) issued a Licence to Abandon the heavy water plant in 2014 [10].

- Radioactive Waste Operation Site 1: The Radioactive Waste Operation Site 1 was established to manage the low and intermediate level wastes from the Douglas Point and Pickering A Nuclear Generating Station. The site consists of a number of in-ground waste storage structures containing solid low and intermediate level wastes. In the 1990s and early 2000s a portion of the in-ground structures were decommissioned and the associated waste relocated to the WWMF. The site has not received waste since 1976 and the remaining storage structures remain in a caretaking mode.
- Spent Solvent Treatment Facility (SSTF): The STTF was established in the 1990s to store and process boiler cleaning waste (spent solvent) consisting of ethylenediamine tetra-acetic acid (EDTA) and metals such as copper, iron, zinc and nickel. The SSTF has not accepted spent solvent since 2003 and remains in a caretaking mode. The majority of the spent solvent stored at the STTF, with the exception of a limited volume in the heels of the storage tanks, has been disposed of offsite at an approved disposal facility.

A Deep Geologic Repository (DGR) has been proposed to be built within the OPG-retained land. The DGR will be comprised of two shafts, a number of underground emplacement rooms, and support facilities. The DGR will be used for the long-term management of L&ILW currently managed in the WWMF and other L&ILW to be generated from OPG-owned Nuclear Generating Stations.

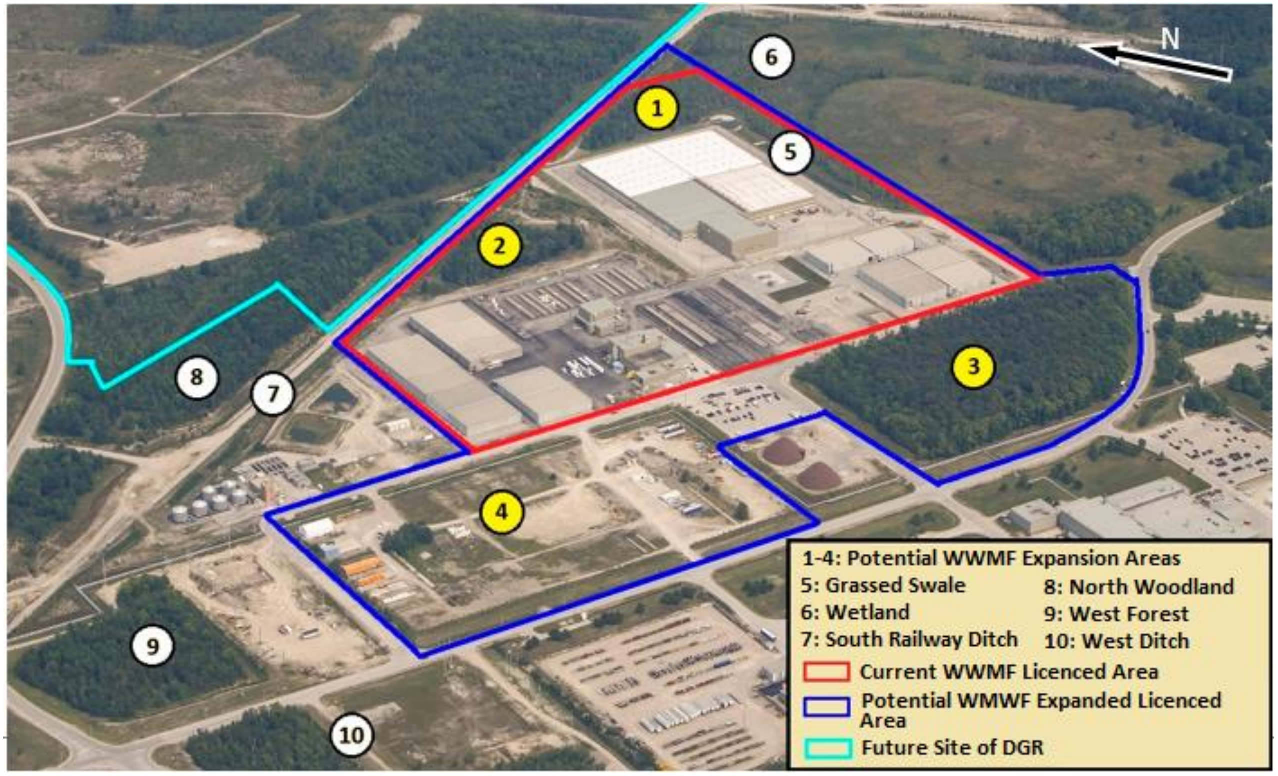


Figure 2-4: Potential WWMF Expansion Areas

2.1.2 Other Facilities at the Bruce Nuclear Site

As shown in Figure 2-2, there are other facilities within the Bruce nuclear site, including:

- Bruce Nuclear Generating Station A (BNGS-A) and Bruce Nuclear Generating Station B (BNGS-B) operated by Bruce Power;
- Douglas Point Waste Management Facility owned by Canadian Nuclear Laboratories, formerly known as Atomic Energy of Canada Ltd. (AECL); and,
- Hydro One Facilities (switchyard, switching stations and transformer stations).

A brief description of these facilities are provided below.

2.1.2.1 Bruce Nuclear Generating Stations

Bruce Power operates BNGS-A and BNGS-B, which each house four CANDU® reactors. All of these units are currently operational and produce a total of ~6,200 megawatts of electricity for the Ontario grid.

BNGS-A is located on the north-west corner of the Bruce nuclear site, about 2.5 km to the north-east of Douglas Point, while BNGS-B is located at the south-west corner, about 0.8 km to the south of Douglas Point.

The BNGS-A section includes part of a 914 m exclusion zone surrounding the BNGS-A powerhouse structure and the associated Lake Huron water lots. These portions are controlled by Bruce Power. Similarly, the BNGS-B section includes part of a 914 m exclusion zone extending from the BNGS-B powerhouse structure to the northern part of Inverhuron Park which is owned by OPG and leased to the Ministry of Natural Resources and Forestry. The four units of BNGS-A were originally put into service in 1977 and the four BNGS-B units were put into service between 1984 and 1987 [5]. Currently all eight units are in operation.

There are several support facilities located on the site, including the Bruce Steam Plant, the Central Maintenance and Laundry Facility, garages, warehouses, workshops, a sewage processing plant and various administrative buildings.

The Bruce nuclear site is fenced and access to the Bruce nuclear site is restricted and is controlled by Bruce Power security personnel. Under the Bruce nuclear site services agreement, Bruce Power also provides security services for the protected area at the WWMF.

2.1.2.2 Douglas Point Waste Management Facility

The Douglas Point Waste Management Facility is owned by Canadian Nuclear Laboratories. The facility consists of a permanently shut down, partially decommissioned prototype 200-megawatt CANDU® reactor and associated structures and ancillaries. This facility is presently in the long term "Storage with Surveillance" phase of a decommissioning program.

2.1.2.3 Hydro One Facilities

Hydro One owns and operates a number of assets within the Bruce nuclear site. These include, but are not limited to, office and workshops for maintenance, switchyards at BNGS-A / BNGS-B, switching stations and transformer stations.

2.2 Description of the Natural and Physical Environment

The natural and physical environment of the WWMF and the surrounding area is described in this section. Where necessary, the information for the Bruce nuclear site and adjacent off-site area is also provided.

2.2.1 Meteorology

2.2.1.1 Wind

Wind data for the Bruce nuclear site, such as wind speed and direction, are measured at two meteorological towers, a 50 m on-site tower and a 10 m off-site tower. The 10 m tower is located along Concession 4 to the east of the Bruce Power Visitors' Centre. The 50 m on-site tower is located approximately 250 m north east of the WWMF and measures wind speed and direction at two elevations: 50 m and 10 m. The wind rose data for the period of 2009-2013, based on the monitoring results at the 10 m level from the on-site meteorological tower, are shown in Figure 2-5.

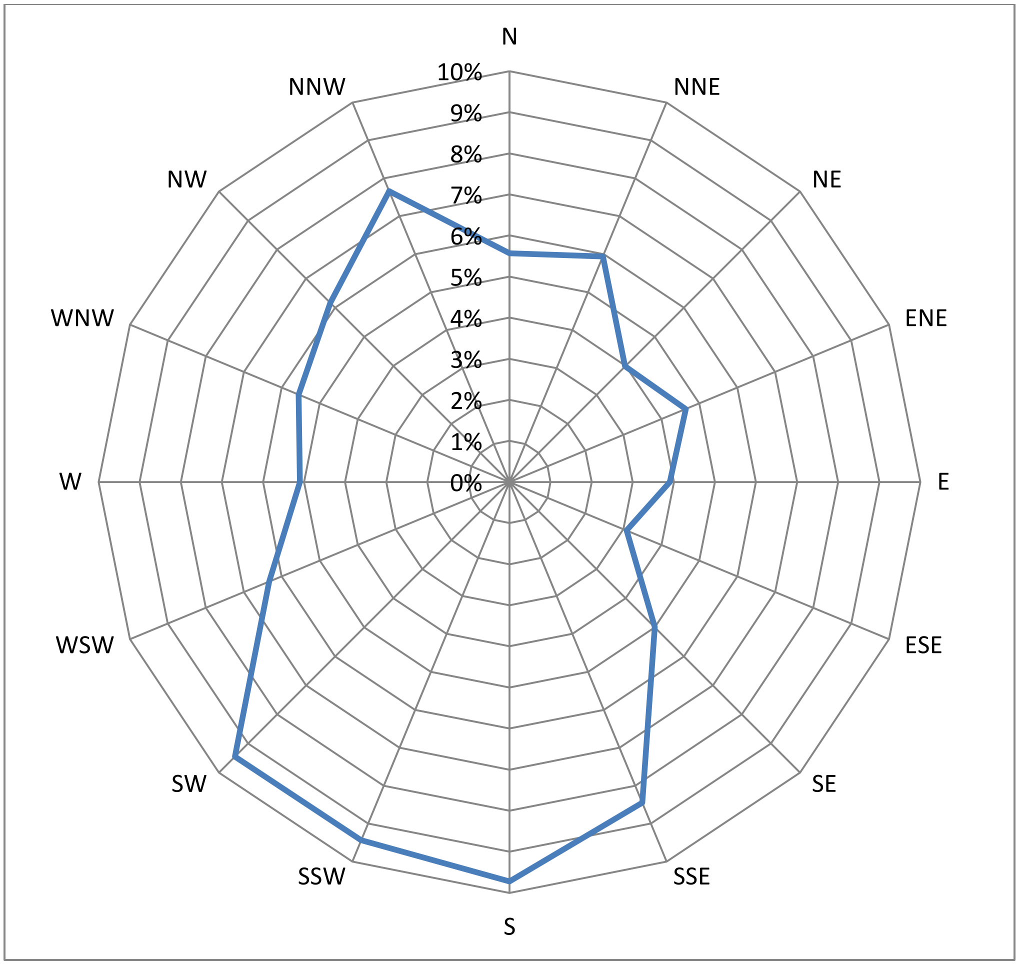


Figure 2-5: Wind Rose Diagram for the Period of 2009-2013

The average wind speed and most frequent direction measured at the 10 m level from the on-site meteorological tower for 2009-2013 have been compared against the Canadian Climate Normals 1981-2010 Station Data from the Wiarton A monitoring station [11] in Table 2-1 below.

Table 2-1: Summary of Winds for Bruce Site and Wiarton A Monitoring Station

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
On-site meteorological tower, 2009-2013													
Average Speed (km/h)	14.5	14.3	12.4	13.2	9.9	8.6	8.7	9.6	10.3	12.8	15.0	15.1	12.0
Most Prevalent Direction	S	S	S	SW	SW	SW	SW	S	S	SSE	SSW	WSW	S
Canadian Climate Normals, 1981-2010 [11]													
Average Speed (km/h)	16.0	14.4	13.7	14.1	11.6	9.8	9.8	10.0	11.6	14.0	15.4	15.8	13.0
Most Prevalent Direction	S	S	W	W	W	W	W	W	S	S	S	S	W

The average wind speed for both data sets follows a similar trend; the wind speed is higher at the beginning of the year in the winter, begins to decrease in May, hits a low in June and July, and increases back up to winter levels by October or November. The yearly average wind speeds for both data sets are also near one another; the yearly average wind speed for 2009-2013 is only 1 km/h less than for 1981-2010. Therefore, the wind speeds observed at the on-site tower are aligned with the Canadian Climate Normals.

The wind direction for the two data sets do differ; the most prevalent wind direction for the 2009-2013 on-site data is S, while for the 1981-2010 data it is W. However, both sets of data have their most prevalent monthly wind directions between S and W. Although the most frequent direction over the year has changed, in general the most prevalent wind direction has not. However, this difference may be due to how the wind direction is recorded. The climate normals report wind direction using the four cardinal directions, while the on-site meteorological data is recorded with the ordinal (SW, SE, etc.) and secondary-intercardinal directions (SSW, etc.). This may cause the wind directions in the climate normals to be approximated to the nearest cardinal direction while the on-site meteorological data is recorded with a higher degree of accuracy.

2.2.1.2 Temperature

The site has a humid continental climate and is characterized by warm summers and cold snowy winters. Air temperature data are collected from the on-site meteorological tower at the 10 m elevation. The temperature for each month over the period of 2009 to 2013, including maximum, minimum and mean values which are based on hourly measurement, is shown in Table 2-2.

Table 2-2: Atmospheric Temperature from On-Site Meteorological Tower (2009-2013)

Month	Hourly Maximum Temperature (°C)	Hourly Minimum Temperature (°C)	Monthly Mean Temperature (°C)
January	7.8	-17.2	-4.5
February	7.3	-14.0	-3.4
March	17.8	-11.5	1.5
April	23.6	-3.3	6.3
May	28.7	2.1	13.1
June	28.6	6.0	16.5
July	29.5	10.7	20.9
August	29.0	11.5	20.4
September	28.1	6.8	12.3
October	19.9	-0.5	9.2

Month	Hourly Maximum Temperature (°C)	Hourly Minimum Temperature (°C)	Monthly Mean Temperature (°C)
November	16.9	-4.4	5.7
December	10.5	-11.3	-1.4
Year	**29.5**	**-17.2**	**8.1**

Average historical extreme maximum, extreme minimum, and monthly mean temperatures at the Wiarton A monitoring station for 1981-2010 [11] can be found in Table 2-3 below.

Table 2-3: Average Temperature, Wiarton A Monitoring Station (1981-2010) [11]

Month	Maximum Temperature (°C)	Minimum Temperature (°C)	Monthly Mean Temperature (°C)
January	7.6	-22.3	-6.3
February	7.1	-22.6	-6.1
March	15.8	-18.9	-1.8
April	23.1	-6.7	5.3
May	26.3	-0.7	11.0
June	29.5	3.5	15.9
July	30.1	7.1	18.9
August	30.0	6.3	18.3
September	27.9	1.4	14.6
October	22.8	-2.4	8.6
November	16.8	-8.8	3.1
December	9.9	-18.2	-2.8
Year	**30.1**	**-22.6**	**6.6**

Compared to the 1981-2010 data, the 2009-2013 data monthly mean temperatures are higher, with the exception of the month of September. The maximum temperatures for 2009-2013 are similar to those for 1981-2010, and the minimum temperatures for 2009-2013 are higher than those for 1981-2010.

2.2.1.3 Precipitation

Precipitation data are collected by Environment and Climate Change Canada at weather stations in the vicinity of the Bruce nuclear site. The mean monthly and annual precipitation data (rainfall and snowfall) for the Wiarton A weather station is shown in Table 2-4 for the period from 2009 to 2013[12].

Table 2-4: Mean Monthly and Annual Precipitation at Wiarton A (2009-2013)

Month	Total Rain (mm)	Total Snow (cm)	Total Precipitation (mm)
January	18.7	105.9	99.7
February	15.6	67.6	74.3
March	26.5	24.4	48.2
April	96.8	14.8	110.9
May	65.6	1.2	66.8
June	115.6	0.0	115.6
July	67.4	0.0	67.4
August	84.1	0.0	84.1
September	112.2	0.0	112.2
October	142.6	2.6	145.2
November	62.7	29.1	89.5
December	21.8	80.5	92.4
Annual	**829.7**	**326.0**	**1106.3**
Maximum	**142.6**	**105.9**	**145.2**
Minimum	**15.6**	**0.0**	**48.2**

Note: Precipitation is the summation of rainfall and snow water equivalent. The station at Wiarton melts the snow to determine water equivalent.

Historical precipitation data for 1981-2010 [11] can be found in Table 2-5 below.

Table 2-5: Mean Monthly and Annual Precipitation at Wiarton A (1981-2010) [11]

Month	Total Rain (mm)	Total Snow (cm)	Total Precipitation (mm)
January	22.6	111.7	99.5
February	21.3	77.7	74.0
March	36.5	39.7	67.4
April	57.9	17.3	73.0
May	83.0	0.5	83.5
June	76.4	0.0	76.4
July	65.8	0.0	65.8
August	77.7	0.0	77.7
September	103.1	0.0	103.1

Month	Total Rain (mm)	Total Snow (cm)	Total Precipitation (mm)
October	97.2	4.1	101.0
November	79.1	44.7	115.7
December	30.0	108.9	110.6
Annual	**750.6**	**404.8**	**1047.9**
Maximum	**103.1**	**111.7**	**115.7**
Minimum	**21.3**	**0.0**	**65.8**

Between 1981 and 2010, the annual rainfall averaged 750.6 mm. Monthly average rainfall ranged between 21.3 and 103.1 mm. For 2009-2013, the annual rainfall averaged 829.7 mm, and monthly average rainfall ranged between 142.6 and 15.6 mm. Therefore average annual rainfall over 2009-2013 has been higher than that from 1981-2010.

Between 1981 and 2010, annual snowfall averaged 404.8 cm; monthly average snowfall ranged between 0 and 111.7 cm. For 2009-2013, annual snowfall averaged 326 cm; monthly average snowfall ranged between 0 and 105.9 cm. Therefore average annual snowfall over 2009-2013 has been lower than that from 1981-2010.

Between 1981 and 2010, annual total precipitation averaged 1047.9 mm; monthly average total precipitation ranged between 65.8 and 115.7 mm. For 2009-2013, annual total precipitation averaged 1106.3 mm; monthly average total precipitation ranged between 48.2 and 145.2 mm. Therefore average annual total precipitation over 2009-2013 has been higher than that from 1981-2010, despite the decrease in snowfall.

2.2.2 Geology

The geologic setting of the Bruce nuclear site is characterized by a variable thickness of glacial sediment overlying carbonate bedrock of the horizontally bedded, relatively undeformed Paleozoic Amherstburg Formation. Glacial sediments thicken eastward from the Lake Huron shoreline where a thin veneer overlies the bedrock surface. The principal stratigraphic units are glacio-fluvial/lacustrine sands and gravel typically underlain by a dense fine-grained glacial till. Inter-till sand lenses and foreshore beach deposits occur locally. The bedrock surface beneath the Bruce nuclear site dips in an easterly direction. The upper few meters of the bedrock surface are fractured and highly weathered. The bedrock consists of near flat lying Paleozoic age dolostone, limestone and shale sedimentary rocks to a depth of around 800m where the Precambrian granitic basement is encountered ([6], [13], [14]).

Beneath the WWMF, the overburden stratigraphy is subdivided into five main units, which are listed below in descending order from ground surface ([13], [14]):

- Surficial sand and gravel unit;
- Upper weathered silty glacial till unit;
- Upper unweathered silty glacial till unit;
- Middle sand/layered till unit; and,

- Lower unweathered silty glacial till unit.

This is illustrated in Figure 2-6.

Grain size distribution in surficial sand gravel unit, based on the 2014 site survey, shows that the soil in the potential expansion areas are generally coarser grained, ranging from sandy silts to silty sandy gravel with an observed high percentage of organic matter. Qualitatively, site observations indicated that the soils have a high amount of organic matter. Given the grain size distribution and the estimated organic content, relatively low erodibility is expected.

The overburden stratigraphy is complex with drift thicknesses ranging between 14 and 19 m, attributed to the laterally discontinuous middle sand/layered till unit. This unit is comprised of well sorted fine to medium sand but coarsens at several locations and is interbedded with thin horizontal layers of silty till. The geometry of the middle sand/layered till unit is irregular with variations in the thickness and elevation.

With few exceptions, the glacial till units are laterally continuous with varied thicknesses. The upper till surface consists of a weathered horizon, with sub-vertical fractures varying in thickness from 0.6 to 2.9 m. Beneath the western sections of the WWMF, the upper and lower unweathered till units are separated by the middle sand/layered till unit. In the central and eastern portions of the WWMF, the two till units merge. In these areas, the two till units cannot be distinguished other than by a slight textural variation in clay content. Within the massive till deposits occasional seams of clay, sand, and sand and gravel occur.

The bedrock underling the surficial deposits consists of Middle Devonian age, buff, silty to sandy dolostone interbedded with dark grey bituminous limestone of the Amherstburg Formation. The bedding structure of the bedrock sequence beneath the WWMF dips gently southeastward, while the bedrock surface dips northeastward.

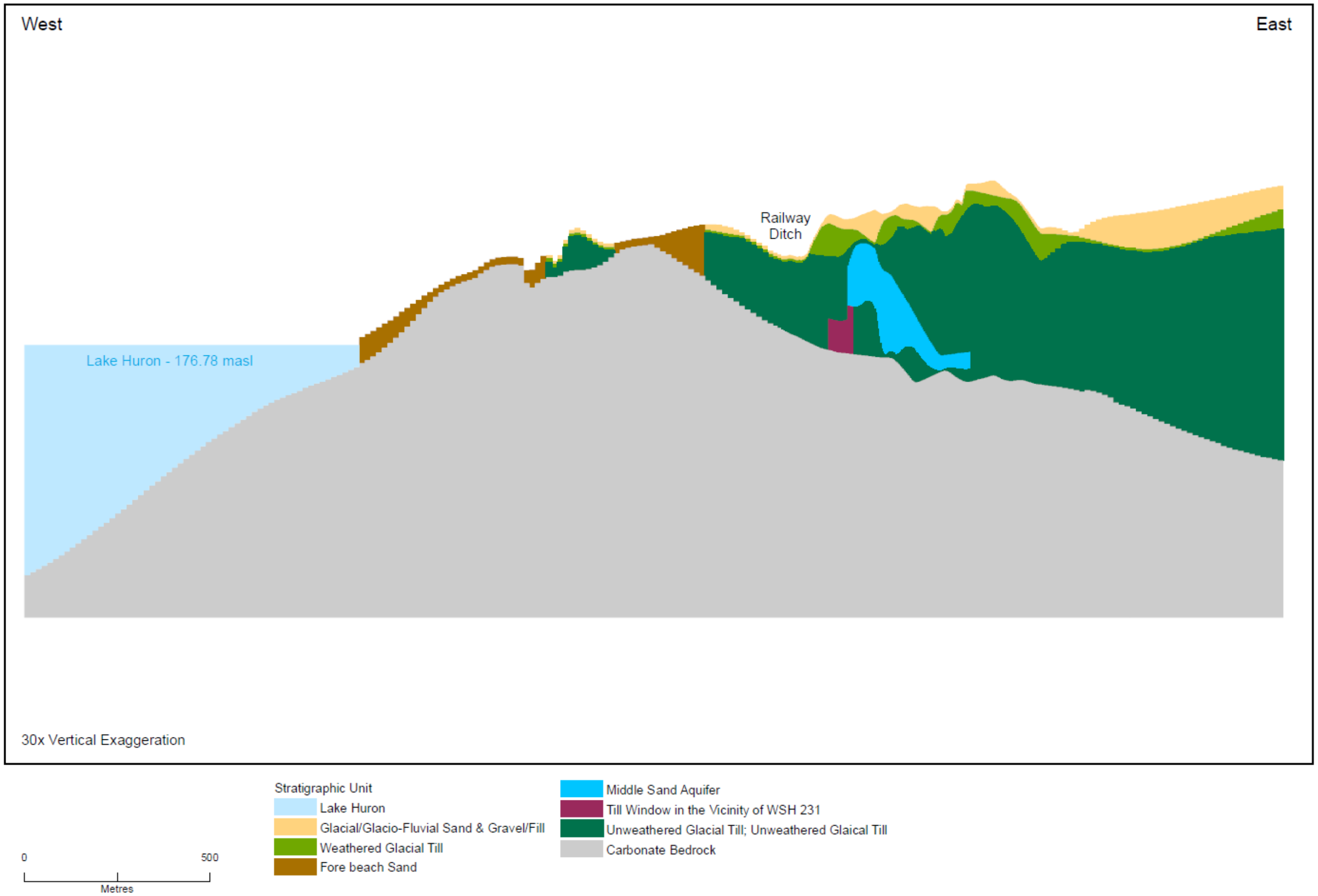


Figure 2-6: West-east Cross Section of Modelled Layers under the Bruce Nuclear Site

2.2.3 Groundwater

Groundwater flow within the surficial deposits and bedrock of the Bruce nuclear site is directed northwestward toward Lake Huron. This is generally sub-parallel to the well-established surface drainage pattern.

Beneath the WWMF, the main hydrostratigraphic units are as follow [13]:

- Middle sand unit;
- Upper and lower silty till units; and,
- Carbonate bedrock unit.

The middle sand unit forms a semi-confined aquifer beneath the WWMF that discharges into the underlying carbonate bedrock. Groundwater levels in the middle sand aquifer vary from 186.4 meters above sea level (masl) at the southwest corner of the WWMF to 182.4 masl in the north storage area where the upper surface of the middle sand unit is approximately 6 m-8 m below the ground surface. The groundwater flow in this area is sub-horizontal to the north central part of the WWMF east with estimated average linear groundwater velocities between 1 and 50 m/year.

The silty till units form a local aquitard beneath the L&ILW storage area. The upper till unit is subdivided into an upper weathered unit and a lower unweathered unit. The weathered portion of the upper till is fractured, although the fracturing has not been found to significantly affect groundwater flux. The average linear groundwater velocities estimated within the silty till units are relatively low, of the order of 0.01 to 0.12 m/year, downwards.

The carbonate bedrock beneath the WWMF is part of a confined regional aquifer complex. The groundwater levels in the bedrock beneath the WWMF are between elevations of approximately 181 and 183 masl. Groundwater flow within the aquifer is horizontal and oriented to the northwest. Groundwater discharge occurs at the Lake Huron shoreline approximately 1.4 km from the WWMF. Groundwater flow rates range between approximately 10 and 140 m/year.

The groundwater levels beneath the WWMF in middle sand aquifer and bedrock aquifer, which could be used to assess groundwater flow, are illustrated in Figure 2-7 and Figure 2-8, respectively. The groundwater quality at the WWMF is further discussed in Appendix B.

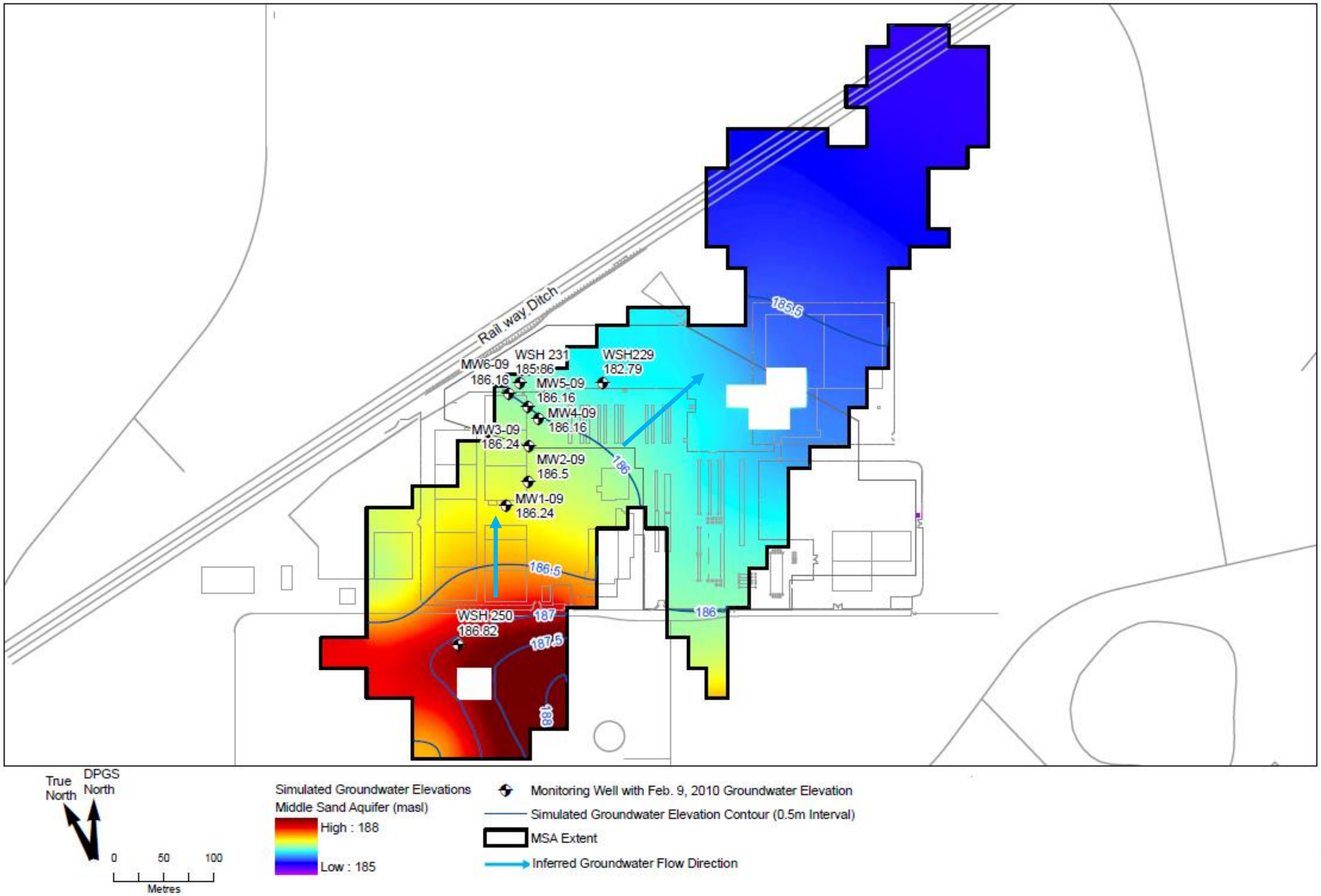
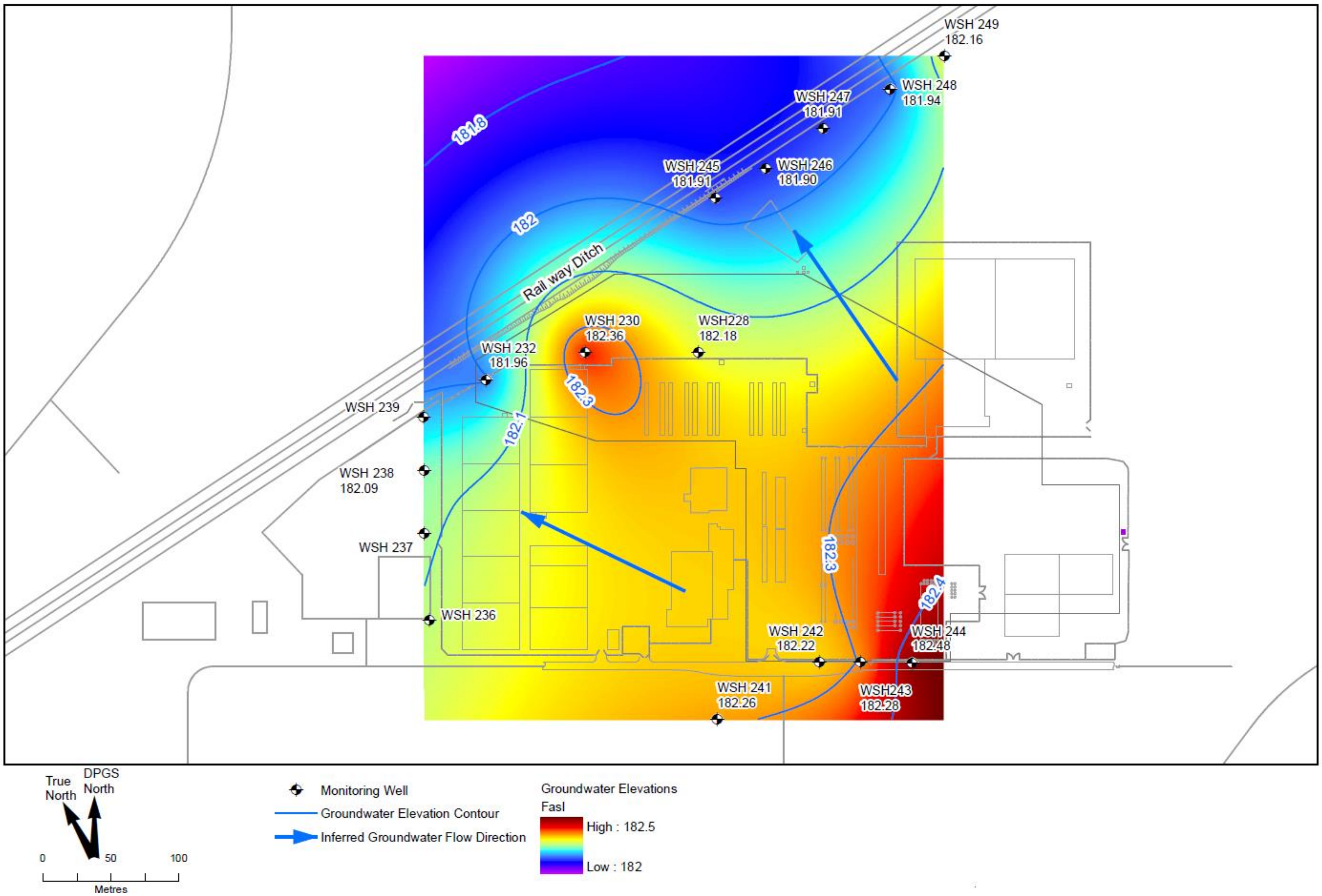


Figure 2-7: Estimated Groundwater Level beneath the WWMF – Middle Sand Aquifer



Note: The water level monitoring data were obtained on Feb 9 2010.

Figure 2-8: Groundwater Level beneath the WWMF – Bedrock

2.2.4 Surface Water

2.2.4.1 Overview

The largest water body near the Bruce nuclear site is Lake Huron, which is used locally for sport and commercial fishing, as well as recreational swimming and boating. There are a number of small rivers and creeks in the vicinity of the Bruce nuclear site that flow into Lake Huron, such as Underwood Creek flowing to the Baie du Doré to the north and the Little Sauble River flowing to Inverhuron Bay to the south as shown in Figure 2-9. Surface water drainage of the Bruce nuclear site is via the South Railway Ditch to Stream C to Baie du Doré, and the West Ditch to Lake Huron.

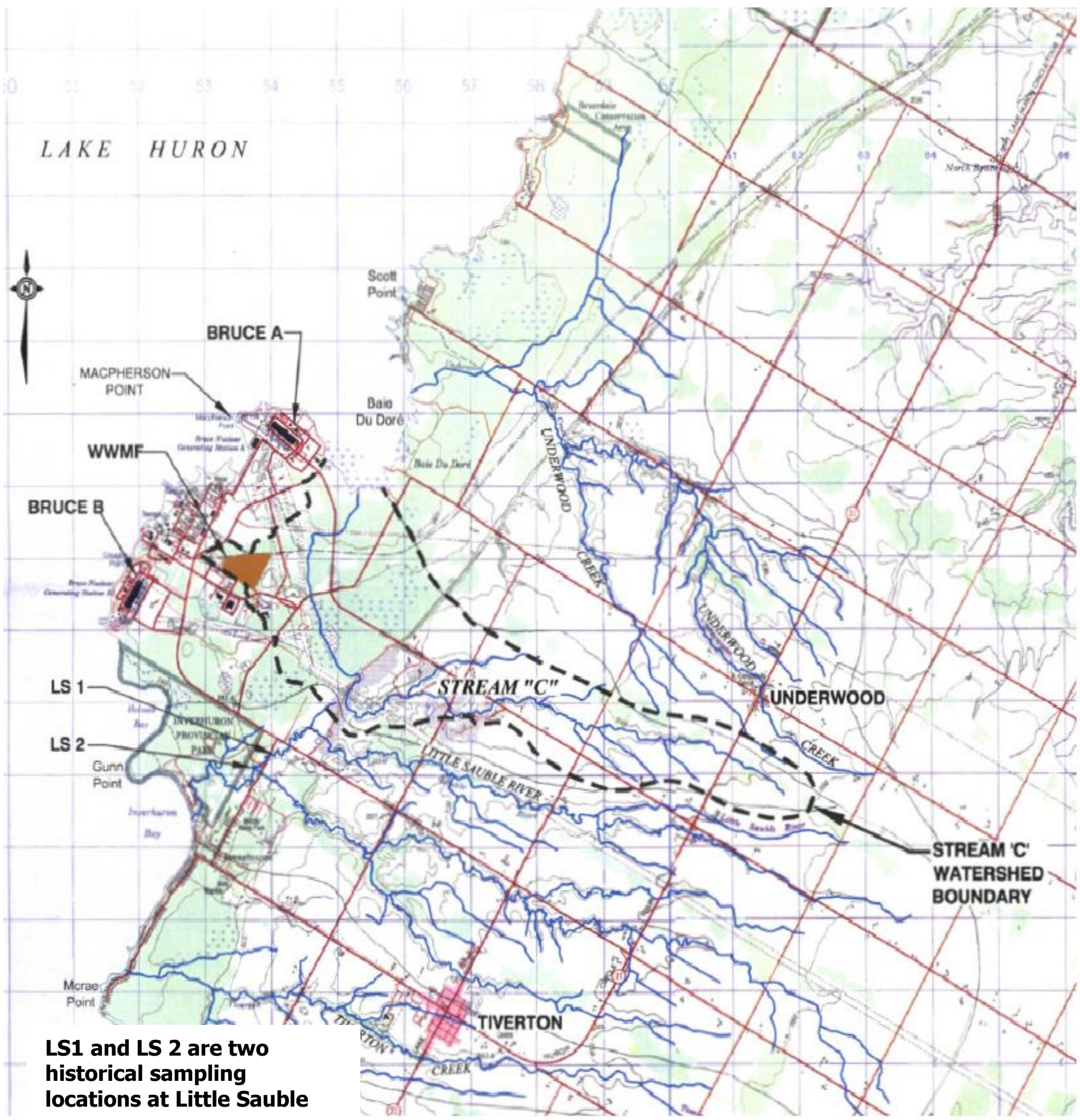


Figure 2-9: Drainage in the Vicinity of the Bruce Nuclear Site [6]

2.2.4.2 WWMF Drainage

There are various surface and subsurface drainage systems within the WWMF. Storm water runoff from the UFDS area and various L&ILW storage structures are directed through these drainage systems to sampling stations prior to discharge to the environment.

Currently, the runoff partially drains into the South Railway Ditch (SRD) that runs along the south side of an abandoned railway spur line north of the WWMF. This abandoned railway spur line north of the WWMF is also known as Siding Road. The SRD is approximately 5 m wide across the top of the ditch. The wetted width of the ditch is approximately 3 m and the mean water depth is 0.15 m. The SRD acts as an intermittent stream and receives drainage from a small catchment area.

In addition, the WWMF drains into a wetland area (also known as the "Wetland") to the east of the site from an intermittent connection with the east storm water hybrid pond. The water in the SRD flows along the east edge of the Wetland. This Wetland has experienced large fluctuations in water level over the years. These fluctuations are dependent on the outflow culvert, which is the point of drainage discharge for the wetland. The outflow of the Wetland drains into the SRD at WTL-1. The SRD subsequently flows to Stream C, which is a man-made stream that was developed to divert water from a former tributary of the Little Sauble. Stream C flows through the Bruce nuclear site to drain into the southwest corner of Baie du Doré.

The average annual water temperature in SRD is 8.5 ºC. The flow rates measured in 2014 and 2015 are shown in Table 2-6.

Table 2-6: Measured Water Flow Rate in South Railway Ditch

Time	2014/04	2014/07	2014/09	2014/10	2015/05
South Railway Ditch (L/s)	17.7	0.2	0	29.8	2.7
West Ditch (L/s)	Not measured	Not measured	0.1	9.2	5.1

There is a ditch called the "West Ditch" west of the WWMF, shown in Figure 2-10. Both east and west branches of the West Ditch convey water from the OPG laydown area and roadside ditching. The West Ditch runs in a westerly direction toward Lake Huron. The average annual water temperature in West Ditch is 8.5ºC, the same as the SRD. The measured flow rates at WD-3 are shown in
Table 2-6.

The drainage in the vicinity of the WWMF is illustrated in Figure 2-10. Photographs of the aquatic environment, including the surface water sampling points, at the WWMF are given in Figure 2-11 to Figure 2-17. The location of the illustrated sampling location is given in Figure 4-4.

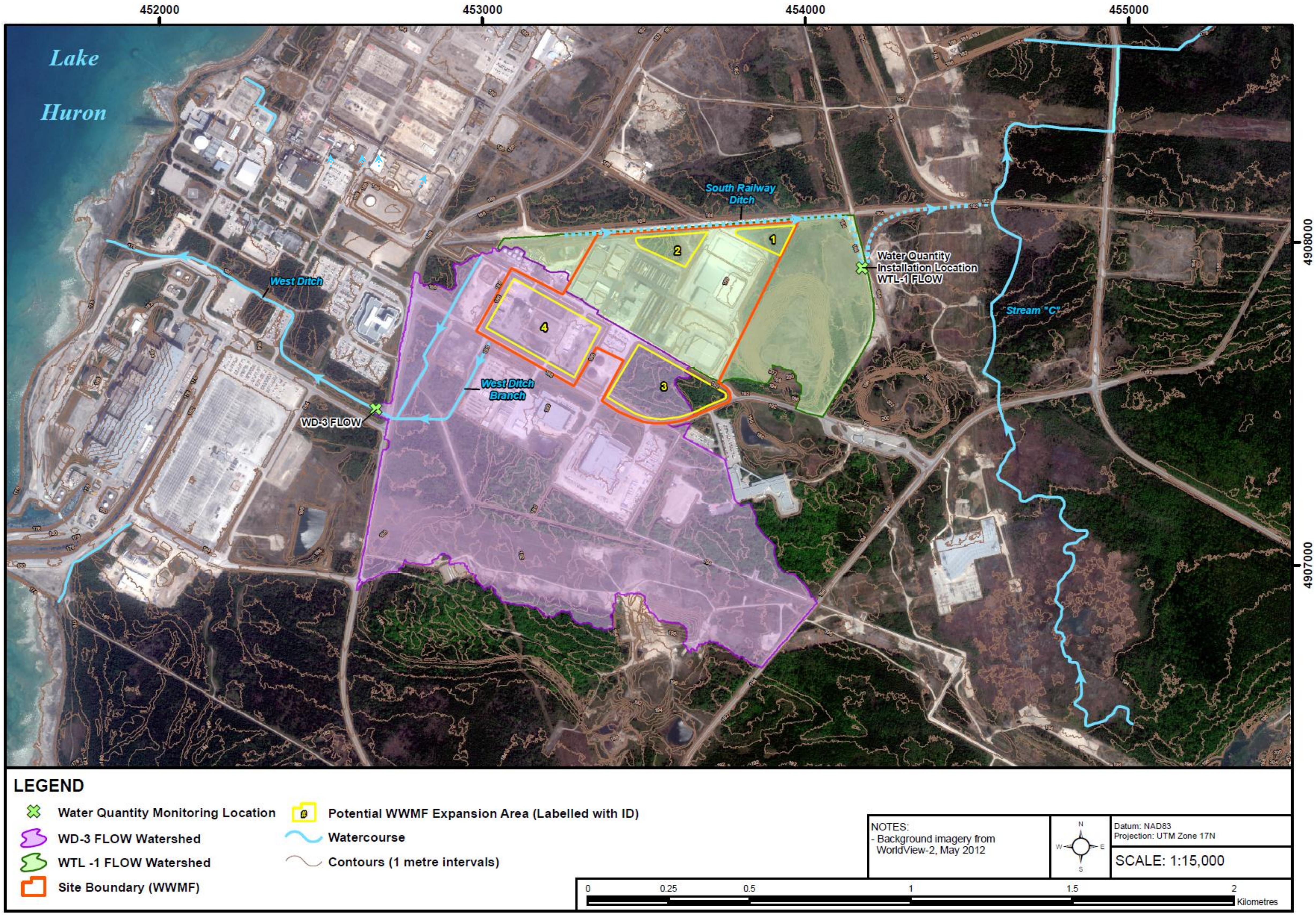


Figure 2-10: Drainage from the WWMF to the Surrounding Environment

Figure 2-11: South Railway Ditch (SRD-1) – Looking west at SRD-1

Figure 2-12: South Railway Ditch (SRD-2) – Looking west at SRD-2

Figure 2-13: South Railway Ditch (SRD-3) – Looking west at SRD-3

Figure 2-14: South Railway Ditch (SRD-4) – Looking north at SRD-4

Figure 2-15: Wetland (WTL-1) – Looking west at WTL-1

Figure 2-16: Grassy Swale (GS-1) – Looking west at GS-1

Figure 2-17: West Ditch (WD-4) – Looking south east at WD-4

2.2.5 Terrestrial Environment

A biophysical inventory survey of the Terrestrial Monitoring Area was undertaken to update the terrestrial data from previous Environmental Assessments, with efforts focused around the WWMF (see Figure 2-18). The Terrestrial Monitoring Area was selected based on ecological barriers around the proposed expansion areas including hard forest edges (roads), major ecosite changes from the previous surveys (corridors) and areas of potential environmental effect due to the WWMF Expansion Project. The biophysical inventory comprised a number of specific field surveys which were conducted during the spring, summer and fall of 2014. The three main terrestrial-related components completed as part of the 2014 field surveys included:

- Terrestrial Habitat;
- Wildlife; and,
- Significant Species.

The survey locations are shown in Figure 2-19. The results of the surveys are summarized below.

Different ecosites were identified within the Terrestrial Monitoring Area. These ecosites are described using the *Ecological Land Classification for Southern Ontario: First Approximation and its Applications* and their locations are illustrated in Figure 2-20 [15]. Images of the ecosites are shown in Figure 2-22 to Figure 2-38.

Significant wildlife habitats were confirmed within the Terrestrial Monitoring Area. As shown in Figure 2-21, these significant wildlife habitats include the following:

- Amphibian Woodland Breeding Habitats;
- Amphibian Wetland Breeding Habitats;
- Special Concern and Rare Wildlife Species Habitat;
- Turtle Wintering Areas;
- Deer Yard Areas; and,
- Terrestrial Crayfish Habitat.

Vegetation and wildlife communities located within the Terrestrial Monitoring Area for the proposed future WWMF expansion activities were identified. These communities are typical of those found in the Lake Simcoe-Rideau Ecoregion[8]. Upland communities and ecosites consist of deciduous, mixedwood, coniferous and cultural habitats. Wetland communities and ecosites consist of swamps, marshes and open water wetlands.

Four species listed as Endangered or Threatened under the provincial Endangered Species Act (ESA) were confirmed within the Terrestrial Monitoring Area, including:

- Barn Swallow;
- Eastern Meadowlark;
- Little brown myotis; and,
- Butternut.

In addition, two species listed as Endangered under the provincial ESA, northern myotis and eastern small-footed myotis, may occur within the Terrestrial Monitoring Area. These species were observed on OPG-retained lands and other areas within the Bruce nuclear site. The Species at Risk (SAR) wildlife and other significant species were observed during their respective breeding/maternity roost colony seasons.

Six species listed as Special Concern under the provincial ESA were confirmed within the Terrestrial Monitoring Area as shown in Figure 2-21, including:

- Golden-winged Warbler;
- Olive-sided Flycatcher;
- Eastern Wood-Pewee;
- Wood Thrush;
- Snapping turtle; and,
- Monarch butterfly.

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[8] The Bruce nuclear site is in the Lake Simcoe-Rideau Ecoregion.

Rusty Blackbird was also confirmed within the Terrestrial Monitoring Area. Rusty Blackbird is listed as Special Concern under Schedule 1 of the federal Species at Risk Act (SARA), but is not listed under the provincial ESA.

A summary of the significant species that were observed during the 2014 field surveys on the Terrestrial Monitoring Area within the Bruce nuclear site, and their status in the provincial ESA and in Schedule 1 of the federal SARA, can be found in Table 2-7. Note that these statuses can get updated, but are current as of Feb 23, 2016.

Table 2-7: Significant Species within the Terrestrial Monitoring Area

Species	Status	
	Provincial ESA	**Federal SARA Schedule 1**
Barn Swallow	Threatened	No status
Butternut	Endangered	Endangered
Eastern Meadowlark	Threatened	No status
Eastern Small-footed Myotis*	Endangered	No status
Eastern Wood-Pewee	Special Concern	No status
Golden-winged Warbler	Special Concern	Threatened
Little Brown Myotis	Endangered	Endangered
Monarch Butterfly	Special Concern	Special Concern
Northern Myotis*	Endangered	Endangered
Olive-sided Flycatcher	Special Concern	Threatened
Rusty Blackbird	No status	Special Concern
Snapping Turtle	Special Concern	Special Concern
Wood Thrush	Special Concern	No status

*possibly present based on analysis of monitoring results

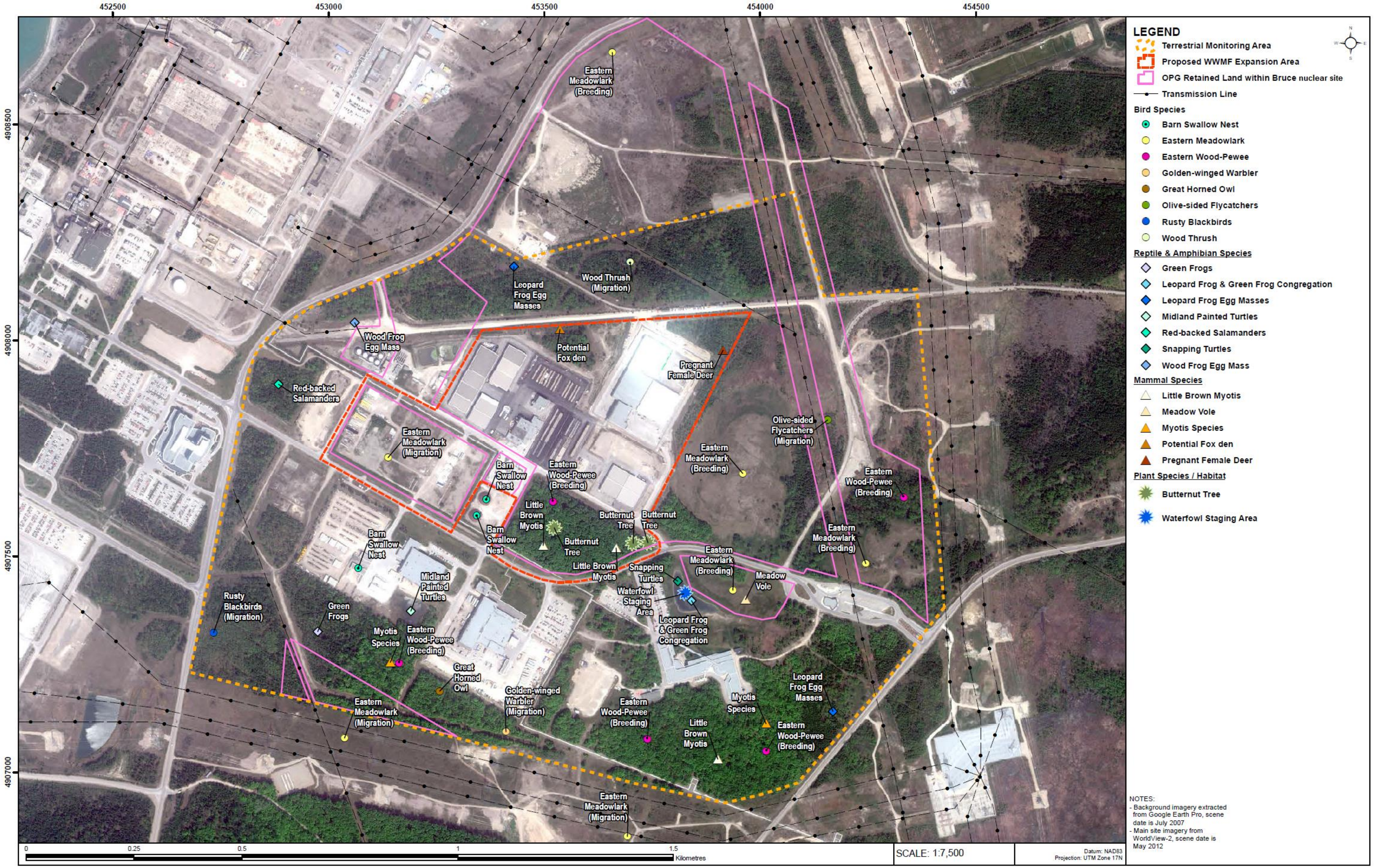
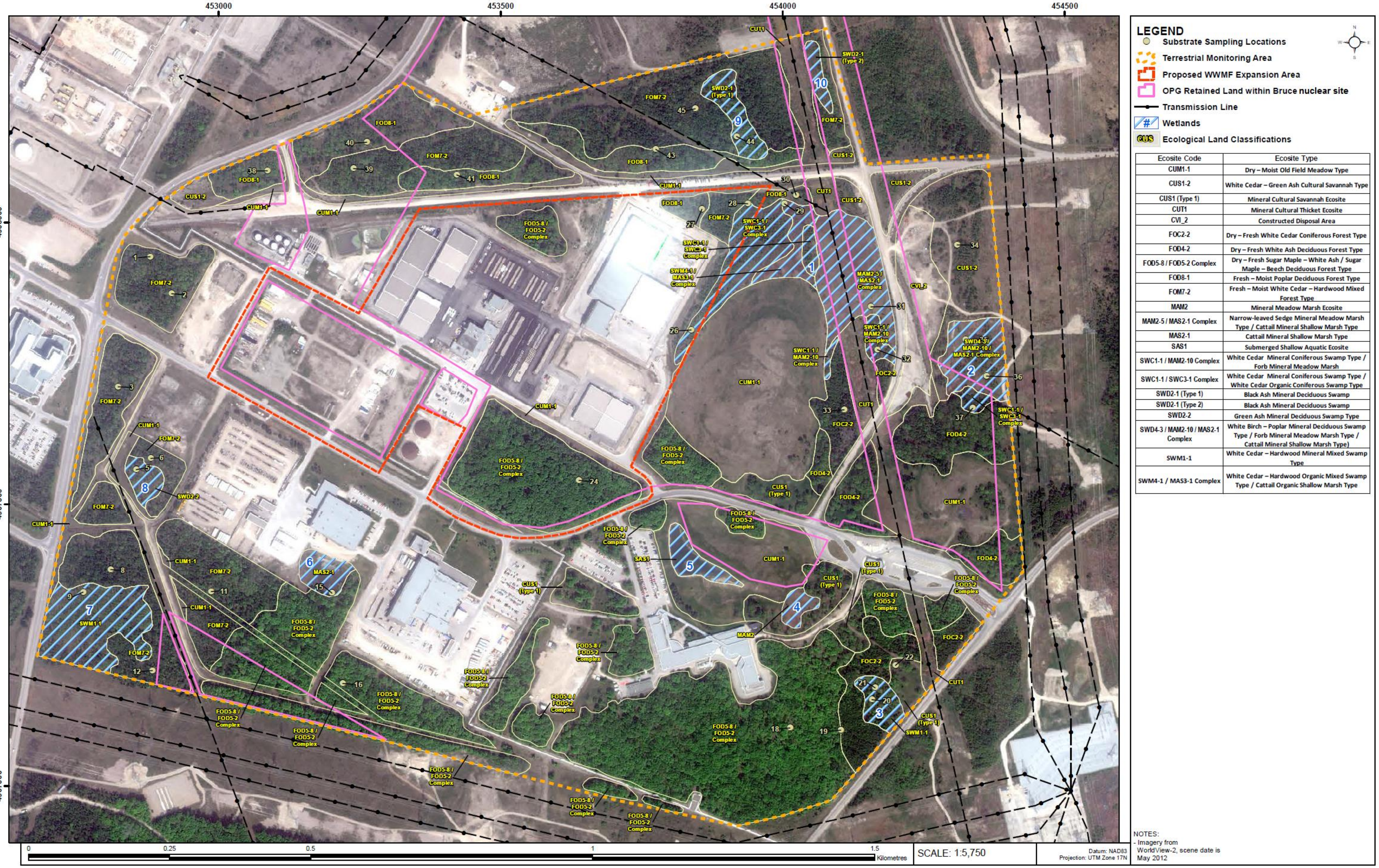


Figure 2-18: WWMF Terrestrial Monitoring Area

Figure 2-19: Wildlife and Substrate Sampling Survey Locations



Ecosite Code	Ecosite Type
CUM1-1	Dry – Moist Old Field Meadow Type
CUS1-2	White Cedar – Green Ash Cultural Savannah Type
CUS1 (Type 1)	Mineral Cultural Savannah Ecosite
CUT1	Mineral Cultural Thicket Ecosite
CVI_2	Constructed Disposal Area
FOC2-2	Dry – Fresh White Cedar Coniferous Forest Type
FOD4-2	Dry – Fresh White Ash Deciduous Forest Type
FOD5-8 / FOD5-2 Complex	Dry – Fresh Sugar Maple – White Ash / Sugar Maple – Beech Deciduous Forest Type
FOD8-1	Fresh – Moist Poplar Deciduous Forest Type
FOM7-2	Fresh – Moist White Cedar – Hardwood Mixed Forest Type
MAM2	Mineral Meadow Marsh Ecosite
MAM2-5 / MAS2-1 Complex	Narrow-leaved Sedge Mineral Meadow Marsh Type / Cattail Mineral Shallow Marsh Type
MAS2-1	Cattail Mineral Shallow Marsh Type
SAS1	Submerged Shallow Aquatic Ecosite
SWC1-1 / MAM2-10 Complex	White Cedar Mineral Coniferous Swamp Type / Forb Mineral Meadow Marsh
SWC1-1 / SWC3-1 Complex	White Cedar Mineral Coniferous Swamp Type / White Cedar Organic Coniferous Swamp Type
SWD2-1 (Type 1)	Black Ash Mineral Deciduous Swamp
SWD2-1 (Type 2)	Black Ash Mineral Deciduous Swamp
SWD2-2	Green Ash Mineral Deciduous Swamp Type
SWD4-3 / MAM2-10 / MAS2-1 Complex	White Birch – Poplar Mineral Deciduous Swamp Type / Forb Mineral Meadow Marsh Type / Cattail Mineral Shallow Marsh Type)
SWM1-1	White Cedar – Hardwood Mineral Mixed Swamp Type
SWM4-1 / MAS3-1 Complex	White Cedar – Hardwood Organic Mixed Swamp Type / Cattail Organic Shallow Marsh Type

Figure 2-20: Ecological Land Classification of the Terrestrial Monitoring Area

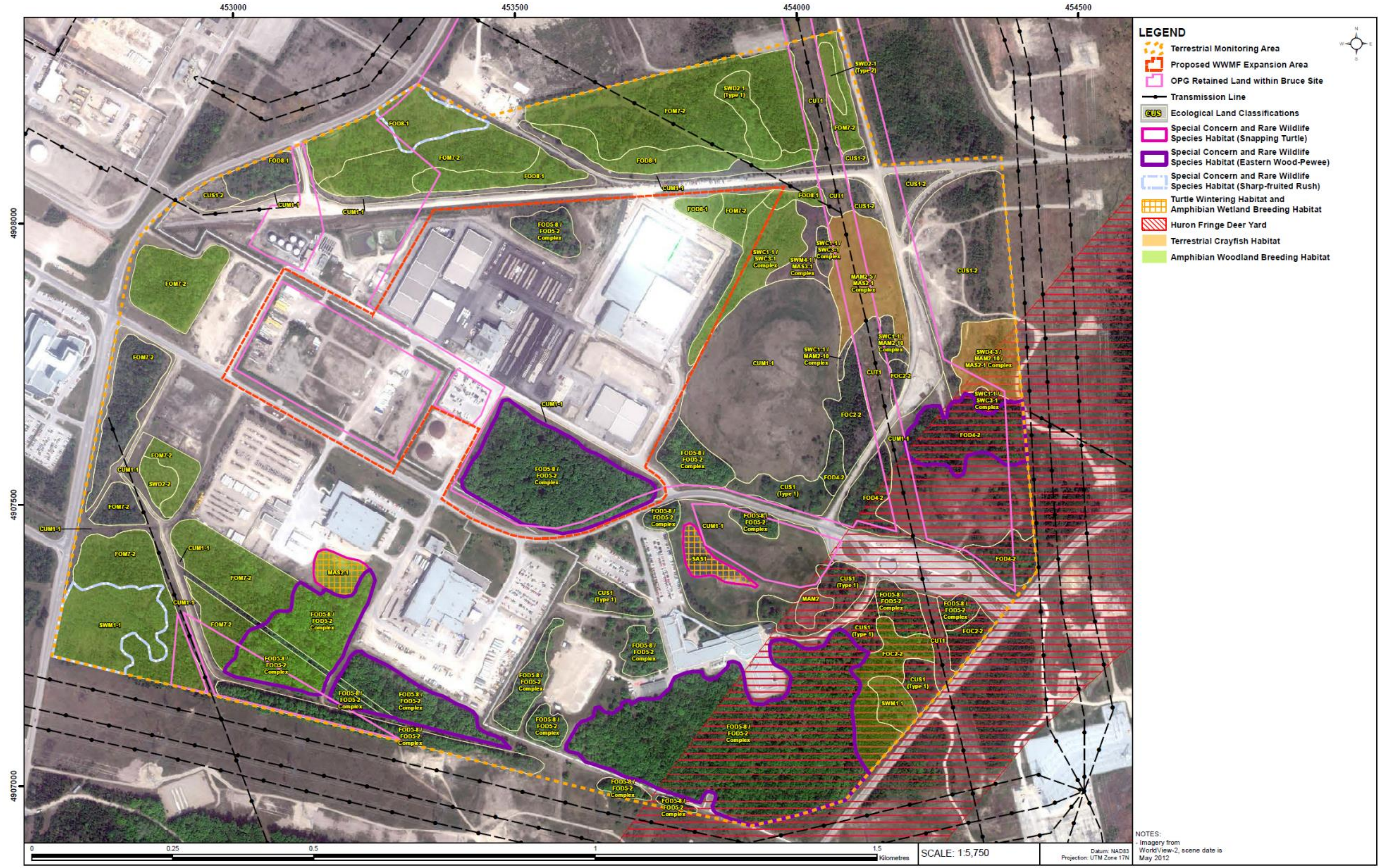


Figure 2-21: Significant Wildlife Habitat

Figure 2-22: FOD8-1 (Fresh – Moist Poplar Deciduous Forest Type)

Figure 2-23: FOD4-2 (Dry – Fresh White Ash Deciduous Forest Type)

Figure 2-24: FOD5-8/FOD5-2 Complex (Dry – Fresh Sugar Maple – White Ash / Sugar Maple – Beech Deciduous Forest Type)

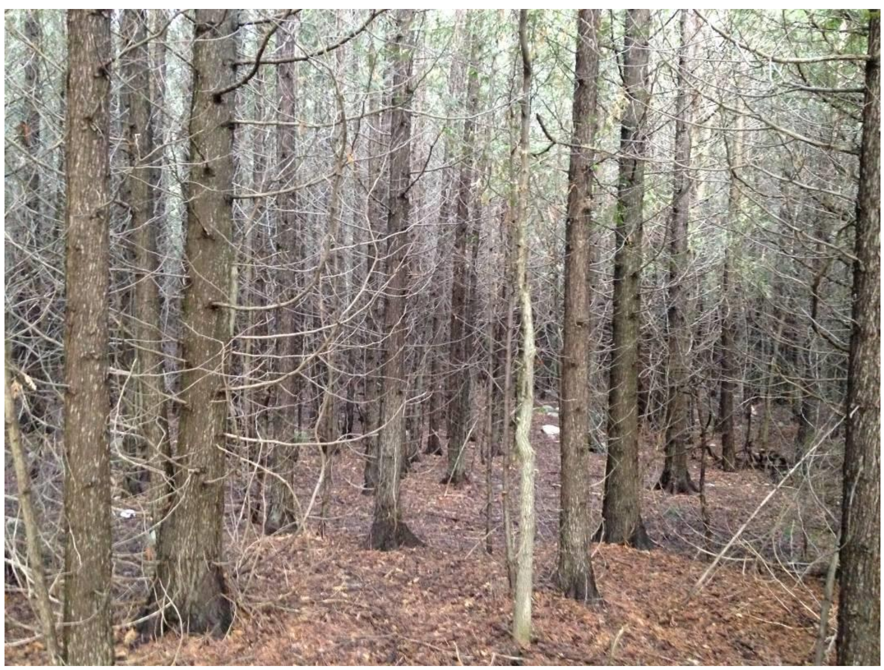


Figure 2-25: FOC2-2 (Dry – Fresh White Cedar Coniferous Forest Type)

Figure 2-26: SWC1-1/MAM2-10 Complex (White Cedar Mineral Coniferous Swamp Type / Forb Mineral Meadow Marsh)

Figure 2-27: CUS1 (Mineral Cultural Savannah Ecosite)

Figure 2-28: CUS1-2 (White Cedar- Green Ash Cultural Savannah Type)

Figure 2-29: CUT1 (Mineral Cultural Thicket Ecosite)

Figure 2-30: CUM1-1 (Dry – Moist Old Field Meadow Type)

Figure 2-31: SWM1-1 (White Cedar – Hardwood Mineral Mixed Swamp Type)

Figure 2-32: SWD2-1 (Type 1) (Black Ash Mineral Deciduous Swamp Type)

Figure 2-33: SWD2-1 (Type 2) (Black Ash Mineral Deciduous Swamp Type)

Figure 2-34: SWD2-2 (Green Ash Mineral Deciduous Swamp Type)

Figure 2-35: SWD4-3/MAM2-10/MAS2-1 Complex (White Birch – Poplar Mineral Deciduous Swamp Type / Forb Mineral Meadow Marsh Type / Cattail Mineral Shallow Marsh Type)

Figure 2-36: MAM2 (Mineral Meadow Marsh Ecosite)

Figure 2-37: MAS2-1 (Cattail Mineral Shallow Marsh Type)

Figure 2-38: MAM2-5/MAS2-1 (Narrow-leaved Sedge Mineral Meadow Marsh Type / Cattail Mineral Shallow Marsh Type)

2.2.6 Aquatic Environment

Aquatic Habitat and Fish Community surveys were conducted in each of three open water seasons, i.e., spring (April), summer (July) and fall (October) of 2014. Surveys were conducted in the vicinity of the WWMF, including the SRD, the Grassed Swale, the Wetland, and the West Ditch. The surveyed areas are shown in Figure 2-39 through Figure 2-41. The results of the surveys are summarized below.

2.2.6.1 Aquatic Habitats

Aquatic habitats in the surveyed area were found to have some heterogeneity between sampling stations (e.g. Wetland versus SRD). Within fluvial drainage ditches, differences in size, gradient, substrate, cover and riparian vegetation exhibited some change from upstream to downstream areas and within proximity to wetland features. The West Ditch exhibited habitat features consistent with an increased gradient and larger particle size substrates at one location (WD-4, see Figure 4-4) compared to other locations.

Surveys conducted at different seasons rendered very similar results. However, seasonal variations in vegetation growth/percent composition between sampling campaigns was evident, as grasses in the riparian zone and aquatic cattail growth was found to be denser at all sampling sites in the summer sampling period. Similarly aquatic vegetation showed an increase in density thereby providing some increased cover opportunity to small-bodied fish.

<u>South Railway Ditch</u>

The SRD originates near Sewage Processing Plant and flows in a straight fashion eastwardly along the northern margin of the WWMF and adjacent to an abandoned railway bed. The ditch continues northeast through a corrugated steel pipe culvert and turns to the southeast interfacing with the Wetland complex. At the Wetland the SRD flows through a corrugated steel culvert at Siding Road to then flow through another corrugated steel culvert, parallel to Siding Road on the east side of the road. The SRD then drains in a northeastwardly direction and ultimately flows into Stream C.

The SRD provides a high level of instream cover as 96 to 100% of the surface area within these locations provided cover for fish. Cover was typically provided in the form of aquatic macrophytes throughout the SRD with woody debris, flat rock and round rock present in lesser quantities. Riparian vegetation was observed along the length of the SRD, including eastern white cedar (*Thuja occidentalis*), horsetail (*Equisetum sp.*), shrubs (red osier dogwood (*Cornus sericea*), alder (*Alnus sp.*), and juniper (*Juniperus sp.*)), sedges (*Scirpus sp.*) and grasses (reed canary grass (*Phalaris arundinacea*) and common reed (*Phragmites australis*)). Substrates within the ditch were found to be dominated by fines (silt and clay) in upstream sections; however an almost equal division of fines and gravel were present in the downstream reaches.

<u>Wetland</u>

Located on the east side of the WWMF study area, the Wetland covers approximately 4 ha and is largely boarded by the Siding Road. The Wetland received drainage from three sources on site which includes the SRD, the Grassed Swale and the Construction Landfill 1 (bounded by the Central Service Road (to the south) and Siding Road (to the east)). More appreciative flows originate from the SRD which continues along the northeastern and eastern margins of the Wetland before passing under the Siding Road on its path to Stream C. The Wetland receives a reduced proportion of surface water from the Grassed Swale than previously reported. As a result of Grassed Swale re-configuration, fluctuations in water levels in the Wetland were largely attributed to precipitation events, which would include surface water from the Grassed Swale once water levels exceeded holding capacity. While surveys did not find evidence to support the presence of groundwater inputs, the isolated nature of the Wetland suggests there is groundwater recharge potential within this water feature. The Wetland was found to be dominated by dense cattail stands, sparsely intermixed with areas of standing water. Surveys in 2014 found that the Wetland is slowing taking on a meadow marsh hydrological regime as few areas of standing water were located. Substrate within the Wetland was made of organic matter (decaying vegetation) (95%) and fines (silts and clay) (5%).

<u>Grassed Swale</u>

During 2013 and 2014 the Grassed Swale was modified to provide an increase in capacity for storm water management and reduce suspended sediment loading and deposition in the downstream environment. The modifications included an overall increase in the size of the Swale and the introduction of permanent pools to provide water quality treatment. The modifications were designed so as to allow for attenuation and flow to remain in the swale up to and including a 10-year storm event. The settling basin at the outlet of the Swale to the Wetland is to provide final polishing. The Swale will ultimately discharge to the Wetland after the water level has reached the outfall crest.

The area directly downstream of the outfall structure is characterized by a cedar swamp with hummocks and pooled water with marginal to no flow. Intermittent flow areas were composed of approximately 30-55% grasses, 20-30% sedges, 20% trees, 5-15% shrubs and <5% ferns. The potential reduced periodicity of a discharge from the Grassed Swale to the Wetland during wet periods may, in time, further influence the standing water conditions observed in the summer of 2014. During 2014 sampling efforts, it was found that the wetted areas of the Grassed Swale were composed of water arum (55%), pondweed (20%), cattails (15%) and algae (10%).

West Ditch

Both east and west branches of the West Ditch convey water from the OPG laydown area and roadside ditching and are generally characterized as cattail choked with some remaining tree stands in riparian areas. The upstream east branch of the West Ditch was found to travel along the perimeter of a laydown area possessing little overhead tree cover. The upstream west branch of the West Ditch flowed alongside a truck path access (approximately 8 to 12 m of separation between path and ditch) and possessed a large amount of overhead tree cover. Flowing south-southwest, these West Ditch branches flowed into a confluence just upstream of the crossing of the Interconnecting Road. Flowing in a straight fashion (without significant meander) the West Ditch continued northwest receiving drainage from a Wetland/storm water feature adjacent to the Bruce Power Support Centre. The West Ditch continues flowing northwest, before ultimately discharging to Lake Huron. During the 2014 fall sampling period, a visual survey of the West Ditch outflow to Lake Huron was carried out. It was noted that both the instream and riparian zone were heavily vegetated. While the instream aquatic vegetation was dominated by rushes, grasses and cattails, the riparian zone was found to have trees (eastern white cedar), shrubs (red osier dogwood) and grasses. Substrate at this section of the West Ditch was found to be largely composed of fines and gravel.

2.2.6.2 Aquatic Communities

The majority of fish were found within the SRD with smaller numbers of fish in the West Ditch, Grassy Swale and the Wetland. The most abundant fish species within the surveyed area included:

- Central Mudminnow (*Umbra limi*);
- Brook Stickleback (*Culaea inconstans*);
- Northern Redbelly Dace (*Chrosomus eos*); and,
- Creek Chub (*Semotilus atromaculatus*).

Other species captured within the surveyed area included

- Fathead Minnow (*Pimephales promelas*);
- Finescale Dace (*Chrosomus neogaeus*);
- Blacknose Shiner (*Notropis heterolepis*);
- Longnose Dace (*Rhinichthys cataractae*);
- Blacknose Dace (*Rhinichthys atratulus*);
- Lake Chub (*Couesius plumbeus*); and,
- White Sucker (*Catostomus commersonii*).

Of the less abundant species, Longnose Dace, Fathead Minnow, Blacknose Shiner and Blacknose Dace were found exclusively in the SRD. Lake Chub and Longnose Dace were captured in the SRD, but only at the most downstream sampling location. Lake Chub are known to inhabit lakes, rivers and creeks where there is an availability of gravel substrates. Longnose Dace prefer large particle size substrates (cobble and gravel). The presence of these species at this location likely indicates connectivity to Stream "C", yet their absence further upstream indicates a reduction in connectivity and habitat availability. White Sucker were captured in the West Ditch during June of 2014. A summary of species presence and absence by water body as assessed in 2014 is provided in Table 2-8. In summary, the aquatic habitats in the drainage ditches of the surveyed area support a warm/cool water small-bodied fish community. The habitats and fish communities identified are indicative of the man-made or influenced drainage features associated with the site which retain some connectivity to larger water bodies. It should be noted that no federal or provincial aquatic Species at Risk were identified inhabiting the drainage features within the survey area during the three seasons sampled in 2014.

Table 2-8: Fish Species Distribution across Surveyed Area in 2014

Common Name	**Scientific Name**	**2014**			
		South Railway Ditch	**West Ditch**	**Grassed Swale**	**Wetland**
Banded Killifish	*Fundulus diaphanus*		X		
Blacknose Shiner	*Notropis heterolepis*	X			
Bluntnose Minnow	*Pimephales notatus*		X		
Brassy Minnow	*Hybognathus hankinsoni*	X			
Brook Stickleback	*Culaea inconstans*	X	X	X	X
Central Mudminnow	*Umbra limi*	X		X	X
Creek Chub	*Semotilus atromaculatus*	X	X		
Common White Sucker	*Catostomus commersonii*		X		
Fathead Minnow	*Pimephales promelas*	X	X		
Finescale Dace	*Phoxinus neogaeus*	X	X		
Lake Chub	*Couesius plumbeus*	X			

Common Name	Scientific Name	2014			
		South Railway Ditch	West Ditch	Grassed Swale	Wetland
Longnose Dace	*Rhinichthys cataractae*	X			
Northern Redbelly Dace	*Chrosomus eos*	X	X	X	
Pearl Dace	*Margariscus margarita*		X		
Spotfin Shiner	*Cyprinella spiloptera*		X		
Western Blacknose Dace	*Rhinichthys obtusus*	X			

X – Represents captured species

Stream C is located to the east and receives drainage from the SRD. It is a former tributary of the Little Sauble River that was diverted to Baie du Doré during the initial development of the Bruce nuclear site in the 1960s. It is the largest stream entering Baie du Doré [16]. Stream C is identified as cold-water fish habitat, as the fish community includes Brook Trout, Rainbow Trout (*Oncorhynchus mykiss*) and Brown Trout (*Salmo trutta*). Spawning activity of Brook Trout, Rainbow Trout, Brown Trout and Chinook Salmon (*Onchorynchus tshawytscha*) has been documented in this stream [5]. Sucker species (*Castostomus spp.*) and cyprinid species including Spottail Shiner (*Notropis hudsonius*) are also known to inhabit or have been observed in Stream C [5].

Lake Huron and its embayments near the Bruce nuclear site provide nearshore and offshore fish habitats. Offshore habitats are deep and provide habitat for cool and cold-water fish species of recreational, commercial and Aboriginal importance. Fishes include Round Whitefish (*Prosopium cylindraceum*), Lake Whitefish (*Coregonus clupeaformis*), Lake Trout (*Salvelinus namaycush*), and Deepwater Sculpin (*Myoxocephalus thompsonii*) [16].

The shallower nearshore areas of Baie du Doré, which are sheltered from coastal effects, support warm and cool water species. Available shallow shoal areas provide spawning, rearing and foraging habitats for species such as Northern Pike *(Esox lucius*), Smallmouth Bass (*Micropterus dolomieu*), and Bowfin (*Amia calva*) [5].

MacPherson Bay is not sheltered from coastal effects and provides less cover than more sheltered embayments [16]. However, during previous studies nearshore species captured have included White Sucker, Longnose Gar (*Lepisosteus osseus*), Emerald Shiner (*Notropis atherinoides*), Spotfin Shiner and Bluntnose Minnow. Round Goby (*Neogobius melanostomus*) was also present in high abundance [16].

Burrowing Crayfish (*Fallicambarus fodiens* and *Orconectes immunis*) inhabit marshy fields, drainage ditches, marshes, ponds, and shallow, slow moving streams with muddy substrates and rooted aquatic vegetation. They are known to inhabit the marsh, swamp and drainage ditches, including the SRD. Burrowing Crayfish are considered of ecological significance as they are at their northern limit with respect to distribution in Ontario. These crayfish construct burrows through clay or silty clay soils into the groundwater table to escape drying habitats associated with seasonal water level fluctuations. Burrowing Crayfish were assumed on site based on the active burrows and chimneys observed. These burrows and chimneys, indicating the continued use of habitat in the vicinity of the WWMF, are most especially within close proximity to the SRD.

Benthic invertebrate communities showed some variability with substrate and perhaps vegetation at the different sampling locations. Diversity in the SRD and Wetland was relatively low and fairly consistent between the upstream and downstream sites. Benthic communities were indicative of depositional habitat with chironomids, oligochaete worms, leeches and freshwater pea clams (family Sphaeriidae) being present in relatively high proportions. Each of these groups of organisms is generally tolerant of depositional and low levels of oxygen [17] yet provide a forage base. These invertebrates provide a forage base for fish and insectivorous birds. Isopods dominated the invertebrate community of the West Ditch. Amphipods, bivalves and elmid beetles and flatworms were also present in lesser proportions. Overall, the families present within the ditch are considered moderately to highly tolerant to low oxygen conditions due to decomposition of organic matter such as decaying aquatic plants (cattails) [17].

2.2.7 Land Use

The Bruce nuclear site is located within the Municipality of Kincardine, in Bruce County, Ontario (population 66,102) [18]. The site is approximately 18 km north of Kincardine (population 11,174) [19] and 17 km southwest of Port Elgin (population 7,555) [20].

The land use adjacent to the Bruce nuclear site consists of agriculture, recreation and rural residential development. Within a 50 km radius of the Bruce nuclear site, there are 250,000 hectares of agricultural farmland. More than 60 percent of the County's land area is dedicated to the agricultural industry [6]; Bruce County includes the Bruce Peninsula and extends to Tobermory in the north, the shores of Lake Huron in the west, Highway 86 in the south, and the intersection of Highway 1 and Huron Bruce Road in the east.

The land adjacent to the Bruce nuclear site is owned by OPG, and consists of a non-resident buffer consisting of mainly unoccupied bush and/or swamp.

Recreational land use includes Inverhuron Park and cottages in the hamlet of Inverhuron (south of the Bruce nuclear site) and Baie du Doré/Scott Point area (north of the Bruce nuclear site). Common recreational activities on these lands include day visits, hiking, camping, hunting (game includes white tailed deer, wild turkey, waterfowl, and small game), and sport fishing [21].

The region surrounding the Bruce nuclear site has little manufacturing industry. A number of small to medium-sized private companies operate a small industrial park, known as the Bruce Eco-Industrial Park (formerly Bruce Energy Centre), just outside of Bruce nuclear site. A small amount of industry, mostly woodworking and light manufacturing, exists in most of the larger communities having populations of over

1,000. Within approximately 20 km of the Bruce nuclear site, there are 10 schools at the elementary and secondary school level.

Local municipalities receive their water supply largely from Lake Huron; Kincardine and Saugeen Shores have water treatment plants that receive water from the lake and distribute this water to Kincardine and Inverhuron Provincial Park (from the Kincardine Water Treatment Plant) and Port Elgin, MacGregor Point Provincial Park, Southampton, and Saugeen First Nation Reserve (from the Saugeen Shores Southampton treatment plant). The Municipality of Kincardine operates a series of groundwater wells which supply water to Tiverton, Scott Point, Underwood, and Armow [21].

The First Nations communities near to the Bruce nuclear site include the Saugeen Ojibway Nation, which is composed of the Chippewas of Saugeen First Nation and the Chippewas of Nawash Unceded First Nation. The Saugeen Ojibway Nation share the Saugeen and Cape Croker Fishing Island Reserve No. 1, located off the western shore of the Bruce Peninsula north of Chief's Point. The Chippewas of Saugeen First Nation Reserve No. 29 is located adjacent to the community of Southampton on the shoreline of Lake Huron between the mouths of the Saugeen and Sauble Rivers, approximately 25 km north of the Bruce nuclear site. The Chippewas of Saugeen First Nation Chief's Point Reserve No. 28 is located at Chief's Point to the north of Sauble Beach at the base of the Bruce Peninsula. The Chippewas of Nawash Unceded First Nation is centred at Cape Croker Reserve No, 27, located on the north side of Colpoy's Bay and the east shore of the Bruce Peninsula north of the town of Wiarton, approximately 70 km north of the Bruce nuclear site [22].

The lands in and around the Western Waste Management Facility are also the traditional territory of two Métis communities. Métis citizens emerged out of the relations of Indian women and European men which resulted in a new Aboriginal people with a distinct identity and culture. This Métis people were connected through the highly mobile fur trade network and distinct Métis settlements emerged along the rivers and watersheds of the province, surrounding the Great Lakes and throughout to the northwest of the province. These settlements formed regional Métis communities in Ontario.

The Georgian Bay Traditional Territory, which is part of the Métis Nation of Ontario, are represented by the rights-bearing Métis of the Georgian Bay Traditional Territory Consultation Committee. This committee is made of three Métis councils: Great Lakes Métis Council, Georgian Bay Métis Council and Moon River Métis Council. The Métis Nation of Ontario asserts it represents a regional Métis community that has aboriginal rights, including spiritual, cultural, socio-economic, harvesting and other traditional practices in the Georgian Bay harvesting area.

The second Métis community is represented by the Historic Saugeen Métis. The Historic Saugeen Métis, an independent, historic Métis community located at Southampton, Ontario, represents the descendants of Métis in the historic Saugeen community prior to settlement. The Historic Saugeen Métis asserts aboriginal communal rights in the Métis Saugeen territory. The community has been along the Lake Huron shoreline with continuity for almost two hundred years. The geographic scope of the contemporary community is described as covering over 275 km of shoreline from Tobermory and south of Goderich, and includes the counties of Bruce, Grey and Huron.

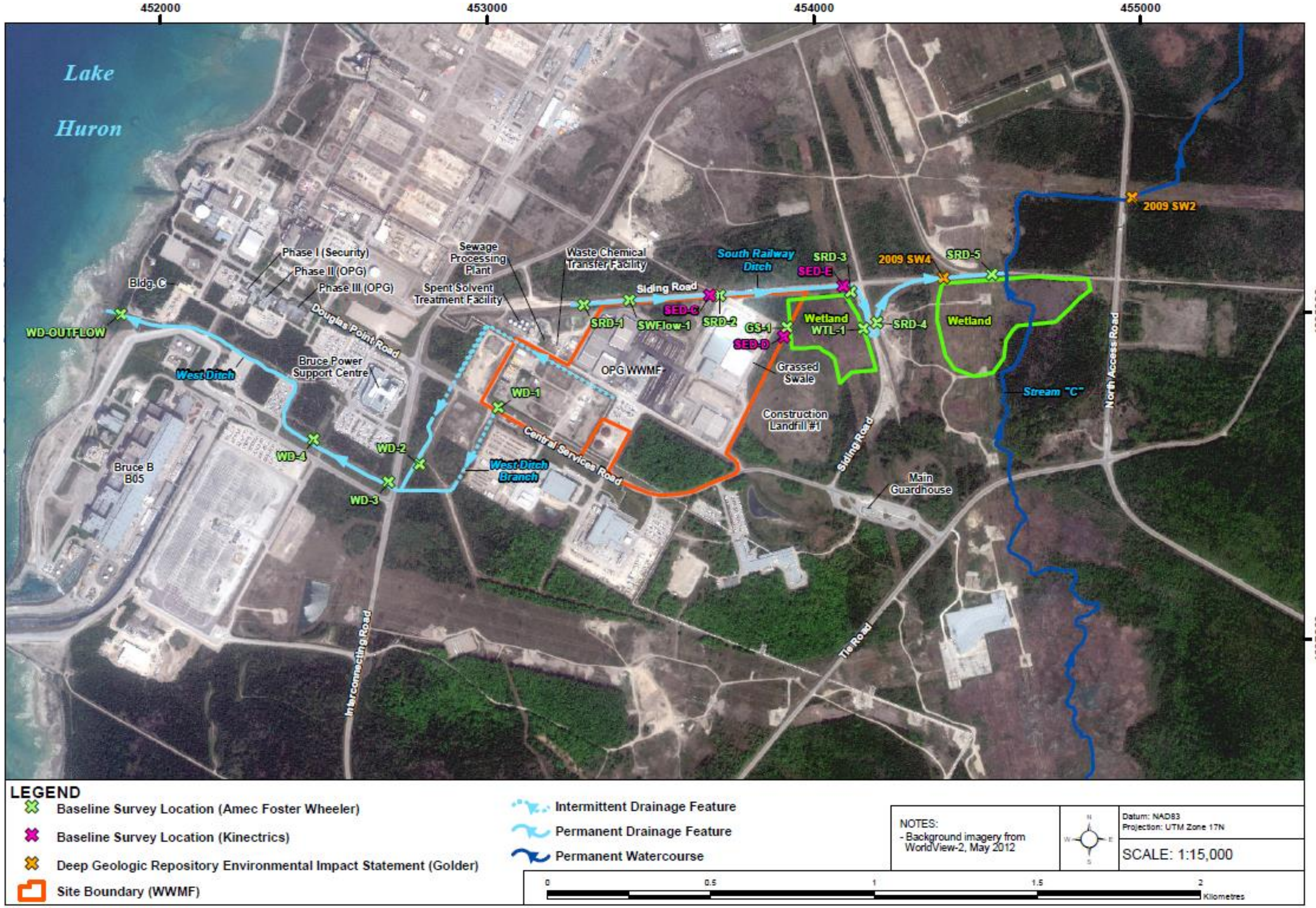


Figure 2-39: WWMF Aquatic Habitat and Fish Community Baseline Monitoring Locations

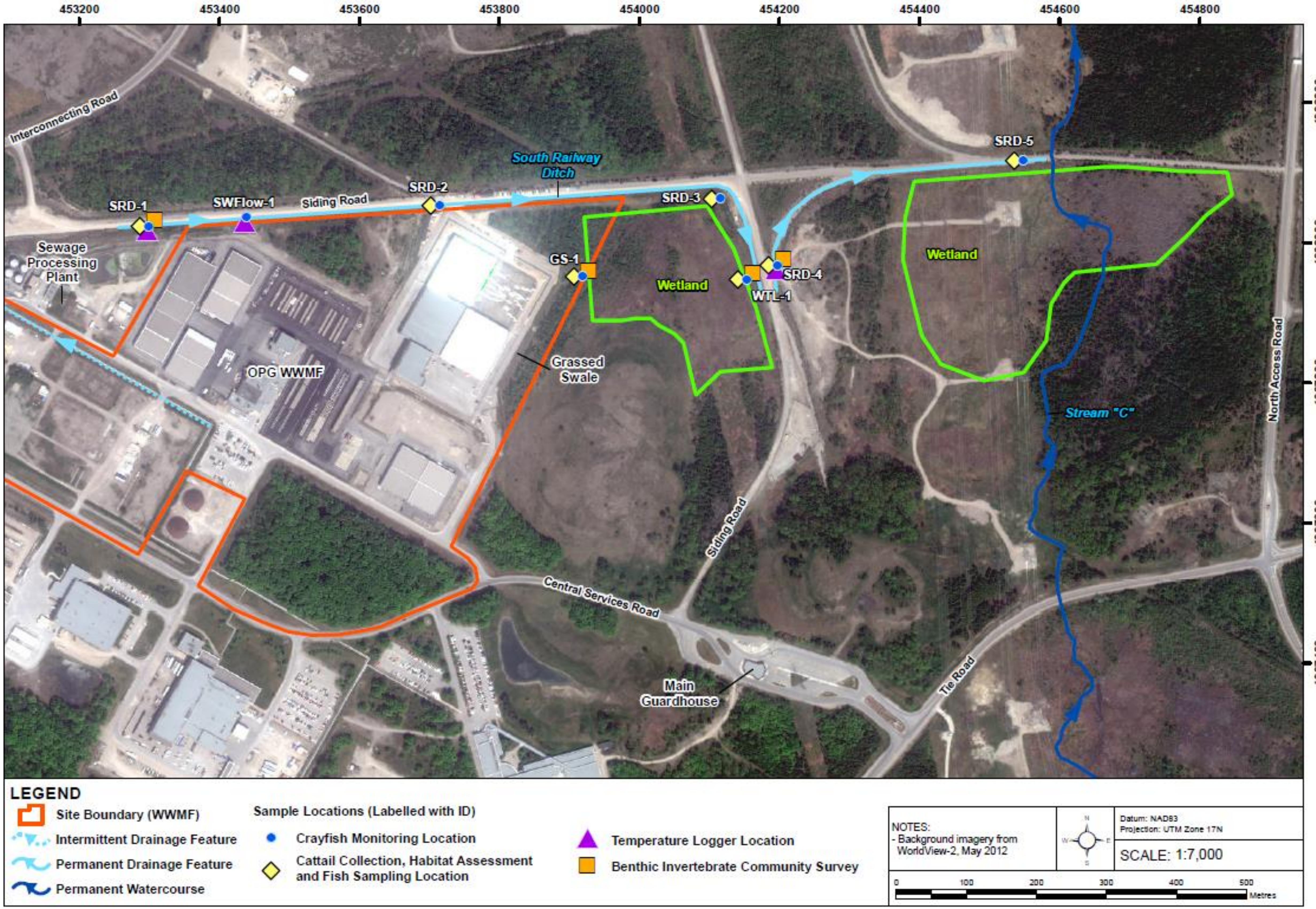


Figure 2-40: South Railway Ditch, Grassed Swale and Wetland Aquatic Habitat and Fish Community Monitoring Locations

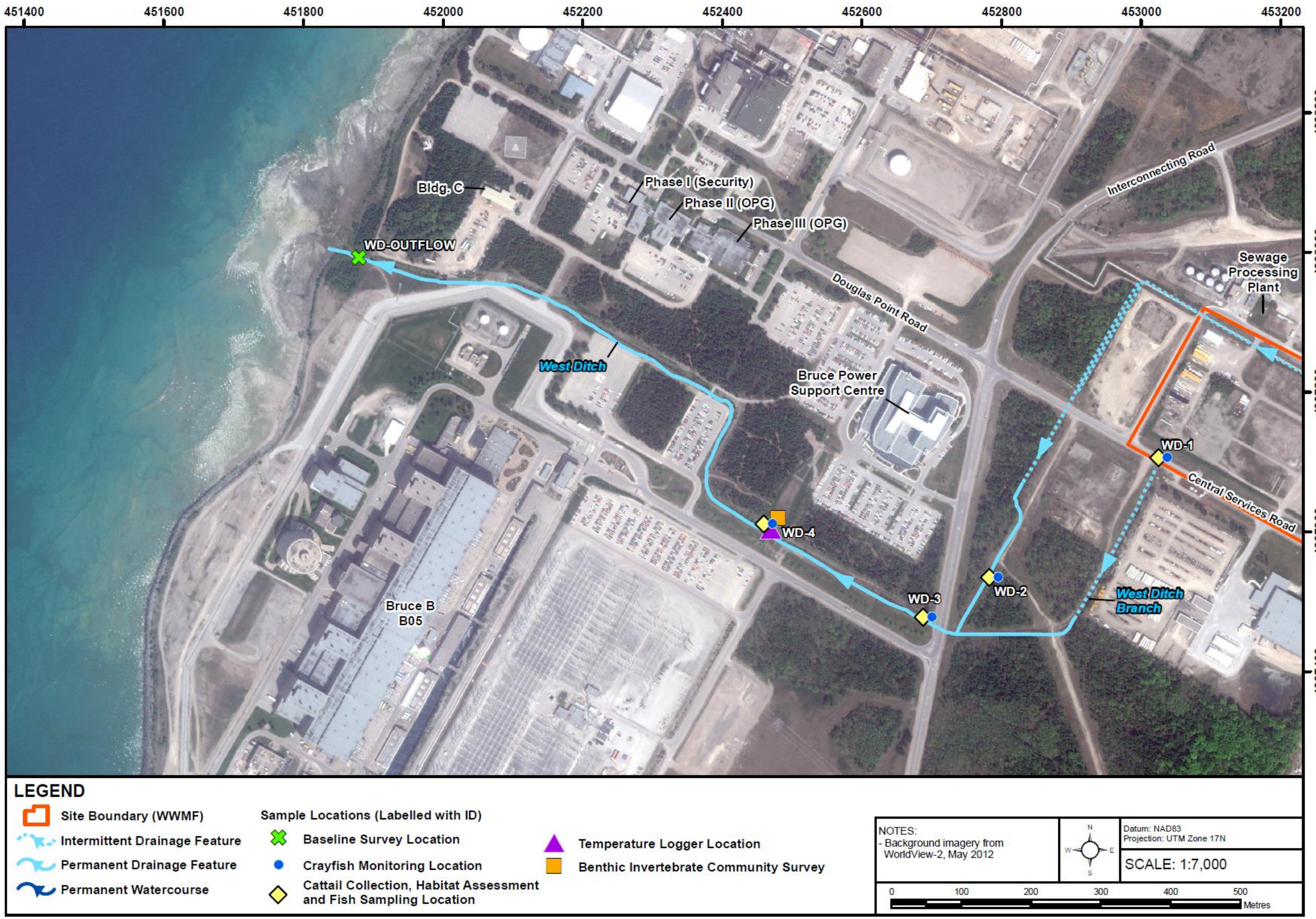


Figure 2-41: West Ditch Aquatic Habitat and Fish Community Monitoring Locations

2.2.8 Population

The area within 100 km of the Bruce nuclear site is rural and consists of small towns and villages only. The 2011 Census indicates a slightly increasing population in Bruce county, with a population change of 1.2% over a period of 5 years (2006 to 2011) [18].

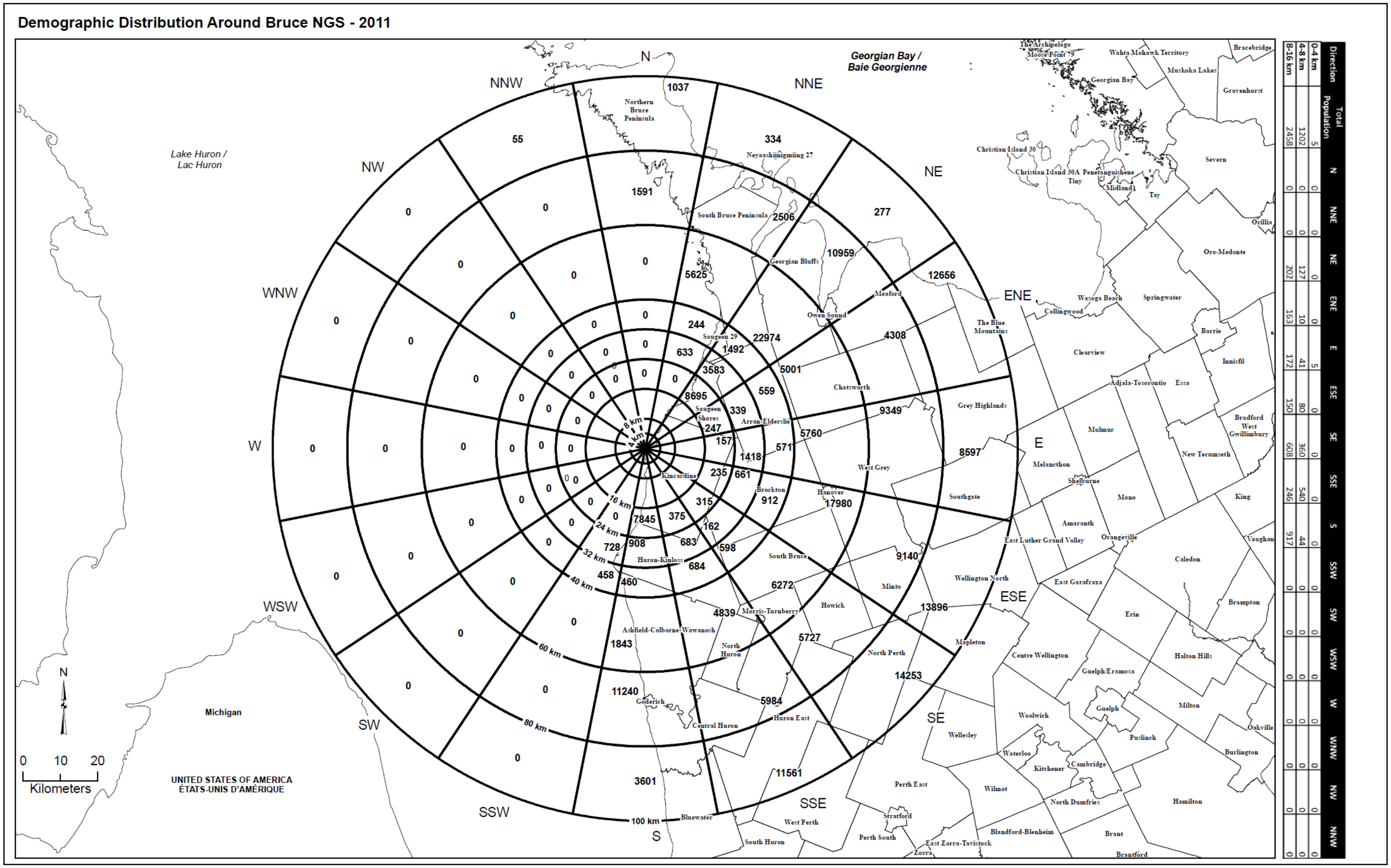
The population distribution around Bruce nuclear site, which was estimated based on population census information in 2011, is given in Table 2-9. The population in each geographic cell is shown in Figure 2-42.

Table 2-9: Population Distribution within 100 km Radius of the Bruce Nuclear Site

Radial Distance (km)	2011 Census Population
0-4	5
4-8	1202
8-16	2458
16-24	17869
24-32	9115
32-40	5978
40-60	70294
60-80	60804
80-100	66267
Total	233992

2.2.9 Effluent and Environmental Monitoring Programs

Radiological and non-radiological substances are released to the environment as the result of the operation of the facilities at the WWMF. To monitor releases and potential environmental effects, effluent monitoring programs and environmental monitoring programs have been established by OPG. These programs are described in Sections 2.2.9.1 - 2.2.9.3.



Source: Statistics Canada, Advisory Services-Toronto
Source: Statistique Canada, Services Consultatifs-Toronto

Figure 2-42: Map of the Region with the Population (2011 Census data) Shown in Each Geographic Cell

2.2.9.1 Effluent Monitoring at WWMF

The airborne and waterborne radiological emissions, as well as non-radiological airborne emissions, to the environment from the WWMF are monitored as part of the WWMF effluent monitoring program. For airborne emissions, the WVRB radioactive waste incinerator stack and ventilation exhaust stack are monitored for tritium (HTO), particulate and iodine-131 (I-131) emissions. Carbon-14 (C-14) emissions are monitored on the incinerator stack; the TPMB ventilation stack is monitored for tritium and particulate emissions; the Used Fuel Processing Building ventilation stack is monitored for particulate emissions.

Waterborne effluent (stormwater runoff) leaving the WWMF is collected at the sampling stations (Figure 2-10) via the Surface and Sub-surface Drainage Systems as discussed previously. The weekly samples taken from each sampling station are analysed for tritium and gross beta activity.

The radiological emissions from WWMF for the last five years (2009-2013) are summarized in Table 2-10 through Table 2-14 ([23] to [27]). As shown in these tables, emissions from the WWMF are at least four orders of magnitude lower than the Derived Release Limits (DRLs) for WWMF[9]. For comparison, the total emissions from the Bruce nuclear site are also presented in these tables. From the tables, it can be seen that the emissions from WWMF account for a small fraction of the total emissions from the Bruce nuclear site.

Table 2-10: Radiological Emission Data for 2009

Media	Radionuclides	WWMF emissions			Total Emissions from Bruce nuclear site (Bq)	WWMF Emissions /Total Emissions (%)
		WWMF Emissions (Bq)	DRL for WWMF	Emission/ DRL (%)		
Air	Tritium Oxide	4.95E+13	2.96E+17	0.02%	1.44E+15	3.44%
	I-131	6.45E+04	1.90E+12[10]	<0.001%	6.04E+07	0.11%
	Particulates-Gross Beta/Gamma	4.08E+04	2.34E+12	<0.001%	1.22E+08	0.03%
	C-14	3.92E+09	1.09E+15	<0.001%	2.45E+12	0.16%
Water	Tritium Oxide	8.83E+10	7.70E+15	0.001%	6.28E+14	0.01%
	Gross Beta/Gamma	1.23E+08	4.56E+11	0.03%	3.49E+09	3.52%

[9] The DRL for a given radionuclide is its annual release rate during normal operation that would cause an individual of the most highly exposed group to receive a dose equal to the regulatory annual dose limit due to exposure to the radionuclide from all potential pathways. In this report, the most recent DRLs for WWMF are used for comparison purposes.
[10] The DRL for iodine is the value for the mixed fission products of iodine.

Table 2-11: Radiological Emission Data for 2010

Media	Radionuclides	WWMF emissions			Total Emissions from Bruce nuclear site (Bq)	WWMF Emissions /Total Emissions (%)
		WWMF Emissions (Bq)	DRL for WWMF	Emission/ DRL (%)		
Air	Tritium Oxide	2.90E+13	2.96E+17	0.01%	1.58E+15	1.84%
	I-131	9.76E+04	1.90E+12[10]	<0.001%	6.63E+07	0.15%
	Particulates-Gross Beta/Gamma	5.61E+05	2.34E+12	<0.001%	7.56E+07	0.74%
	C-14	7.41E+09	1.09E+15	<0.001%	5.10E+12	0.15%
Water	Tritium Oxide	1.56E+11	7.70E+15	0.002%	7.15E+14	0.02%
	Gross Beta/Gamma	5.06E+07	4.56E+11	0.01%	6.78E+09	0.75%

Table 2-12: Radiological Emission Data for 2011

Media	Radionuclides	WWMF emissions			Total Emissions from Bruce nuclear site (Bq)	WWMF Emissions /Total Emissions (%)
		WWMF Emissions (Bq)	DRL for WWMF	Emission/ DRL (%)		
Air	Tritium Oxide	1.99E+13	2.96E+17	0.01%	1.34E+15	1.49%
	I-131	8.95E+04	1.90E+12[10]	<0.001%	7.81E+07	0.11%
	Particulates-Gross Beta/Gamma	1.34E+05	2.34E+12	<0.001%	<5.13E+07	<0.26%
	C-14	3.45E+09	1.09E+15	<0.001%	2.80E+12	0.12%
Water	Tritium Oxide	1.20E+11	7.70E+15	0.002%	8.05E+14	0.01%
	Gross Beta/Gamma	9.02E+07	4.56E+11	0.02%	3.13E+09	2.88%

Table 2-13: Radiological Emission Data for 2012

Media	Radionuclides	WWMF emission			Total Emissions from Bruce nuclear site (Bq)	WWMF Emissions /Total Emissions (%)
		WWMF Emissions (Bq)	DRL for WWMF	Emission/ DRL (%)		
Air	Tritium Oxide	1.04E+13	2.96E+17	0.00%	7.87E+14	1.32%
	I-131	6.06E+04	1.90E+12[10]	<0.001%	2.60E+08	0.02%
	Particulates-Gross Beta/Gamma	1.26E+05	2.34E+12	<0.001%	<2.61E+07	<0.48%
	C-14	1.88E+09	1.09E+15	<0.001%	3.46E+12	0.05%
Water	Tritium Oxide	1.00E+11	7.70E+15	0.001%	1.28E+15	0.01%
	Gross Beta/Gamma	6.80E+07	4.56E+11	0.01%	3.97E+09	1.71%

Table 2-14: Radiological Emission Data for 2013

Media	Radionuclides	WWMF emission			Total Emissions from Bruce nuclear site (Bq)	WWMF Emissions /Total Emissions (%)
		WWMF Emissions (Bq)	DRL for WWMF	Emission/ DRL (%)		
Air	Tritium Oxide	1.43E+13	2.96E+17	0.005%	8.52E+14	1.68%
	I-131	6.38E+04	1.90E+12[10]	<0.001%	1.15E+08	0.06%
	Particulates-Gross Beta/Gamma	3.78E+05	2.34E+12	<0.001%	2.78E+07	1.36%
	C-14	1.96E+09	1.09E+15	<0.001%	3.63E+12	0.05%
Water	Tritium Oxide	1.42E+11	7.70E+15	0.002%	6.15E+14	0.99%
	Gross Beta/Gamma	1.26E+08	4.56E+11	0.03%	4.01E+09	3.14%

In addition, OPG also monitors non-radiological substances released to the environment, which is carried out through WWMF's Environmental Compliance Approval (ECA) related programs. For example, each year OPG has an emission testing program conducted for the incinerator at the WWMF ([28], [29], [30]). The program is required as part of the Ontario Ministry of the Environment and Climate Change (MOECC) Amended ECA No. 8047-8GLPAM. The program tests the emission rates of specific contaminants and demonstrates the facility's ability to meet the allowable emission levels for these contaminants according to the specified point of impingement (POI) concentration limits. The program is reviewed on a regular basis and the results, further discussed in Sections 3.3.2 and 4.3.2.1, are reported to MOECC.

2.2.9.2 Environmental Monitoring at WWMF

OPG has established EMPs to monitor the environment which could be potentially affected by the operation of the WWMF. An environmental baseline monitoring program was also conducted in the vicinity of the WWMF. A brief description of these programs is provided below. The results of these monitoring programs and the use of the monitoring data will be further discussed in Sections 3.3.3, 4.3.2.4, and 4.3.2.5.

<u>WWMF EMP</u>

Environmental monitoring at the WWMF has been conducted for many years. The environmental performance of the WWMF is reported to the CNSC on a regular basis as part of the quarterly operations report. In 2012, a detailed design for the WWMF EMP was developed. A gap analysis and implementation plan for meeting the requirements of CSA N288.4-10 [1] are under development and expected to be completed by December 2017. Some of the results which are relevant to the ERA are used in this assessment. Specifically, radionuclides and metals in water and sediment in the South Railway Ditch and the Grassed Swale were collected in the spring, summer and fall of 2013 and 2014.

<u>Baseline Enhancement Monitoring for Future WWMF Expansion Activities</u>

A thorough review was completed to determine the additional studies required to adequately complete an ERA and predictive effects assessment for potential WWMF site expansion activities. On this basis, the baseline monitoring program was developed and carried out. To characterize the current environment in the vicinity of the WWMF, field sampling and surveys were conducted for different environmental disciplines including terrestrial habitat, aquatic habitat and fish communities, water quantity, surface water and sediment quality, soil quality, groundwater quality, noise, and radiation and radioactivity. Specifically, the samples from different media including surface water, groundwater, vegetation, soil and sediment were analyzed for both radiological and non-radiological contaminants. Soil, vegetation and groundwater samples were collected at various times of the year in 2014 (Table G-1 in Appendix G). Water samples were collected in the spring, summer and fall of 2014, whereas sediment samples were collected in the spring and autumn. Aquatic vegetation (Cattails) was collected during the summer. Relevant results of the monitoring program are provided within Sections 2.0, 3.3, 4.3, and Appendix G of this report.

2.2.9.3 Other Environmental Monitoring Programs

Bruce Power has an established EMP (formerly known as the Radiological Environmental Monitoring Program or REMP) to monitor the environmental effects of the releases from their facilities for many years. The purpose of this EMP is to fulfill regulatory requirements under the Licence Condition of Bruce Power’s Nuclear Power Reactor Operating Licence’s (PROL) 15:00/2014 and PROL 16:00/2014. This licence condition requires Bruce Power to submit an annual environmental monitoring report. The monitoring programs include both radiological and non-radiological (hazardous) substances and quantify the effects on human and non-human biota. The program includes sampling conducted within a 20 km radius of the Bruce nuclear site.

WWMF's radiological emissions are appropriately taken into account in the total dose to member of the public. As such, it will ensure that the overall dose resulting from all nuclear facilities at the Bruce nuclear site is well below the regulatory limit.

2.2.10 Interactions

A summary of interactions between potential stressors from the Bruce nuclear site, potentially affected environmental components and potential receptors is shown in Table 2-15.

Table 2-15: Summary of Interactions among Potential Stressors, Environmental Components and Receptors

Stressors	Release Route/Stressor	Environmental Components	Potential Receptors
Radiological	Airborne	Atmospheric Terrestrial Soil Surface Water Groundwater Aquatic	Residents Workers Flora, Fauna
	Waterborne	Surface Water Groundwater Aquatic	Residents Flora, Fauna
Non-Radiological	Airborne	Atmospheric Terrestrial Soil Surface Water Groundwater Aquatic	Residents Workers Flora, Fauna
	Waterborne	Surface Water Groundwater Aquatic	Residents Flora, Fauna
Physical	Noise	Atmospheric	Residents Workers Flora, Fauna
	Road Kill	Terrestrial	Fauna
	Bird Strikes		

3.0 HUMAN HEALTH RISK ASSESSMENT

In this report, the receptors considered for the HHRA consist of off-site members of the public. Health and safety of on-site workers will be protected by OPG's Radiation Protection Program and Conventional Safety Program, which are discussed below.

3.1 Problem Formulation

3.1.1 Health and Safety of On-site Workers

On-site workers, such as OPG employees, contractors, and visitors, are potentially exposed to radiological and non-radiological emissions resulting from the operation of the WWMF. OPG has developed robust programs to protect their health and safety.

On-site workers receive radiation doses from works and activities relating to the WWMF operations. These exposures are monitored and controlled through OPG's Radiation Protection Program. The Radiation Protection Program is designed to ensure that doses for employees, contractors and visiting members of the public are below the regulatory limits set by the CNSC as given in Table 3-1 [34], and as low as reasonably achievable, social and economic factors being taken into account (ALARA). For example, visitors to the WWMF will always be escorted by qualified WWMF staff.

On-site workers could also potentially be exposed to non-radiological substances. These exposures are considered and controlled through OPG's Conventional Safety Program. The Conventional Safety Program involves a systematic approach to manage risks associated with the activities, products and services of OPG's nuclear operations. The approach includes planning all work through pre-job briefings, and by using approved procedures and operating instructions. All work planned or conducted is subject to safe work planning requirements where safety hazards are identified and mitigating measures, such as the use of personal protection equipment, are identified and implemented.

As it is expected that the health and safety of on-site workers is protected with the implementation of OPG's Radiation Protection Program and Conventional Safety Program, no further risk assessment will be performed for on-site workers.

Table 3-1: Regulatory Exposure Limits

Receptor Group	Exposure Level	Dosimetry Period
Nuclear Energy Workers (NEWs), including pregnant NEWs	50 mSv	1 year
	100 mSv	5 year
Pregnant NEWs	4 mSv	balance of the pregnancy
A person who is not a NEW	1 mSv	1 year

3.1.2 Receptor Selection and Characterization

3.1.2.1 Receptor Selection

For off-site members of the public, the receptors are selected based on the results of the Bruce Power's site-specific survey carried out in 2011. Bruce Power's EMP requires that a site specific survey be conducted at least every five years[11]. The latest survey was conducted in 2011 and gathered information regarding land usage, population distribution, meteorology, hydrology, water sources, water uses and food sources [21]. The information accumulated during the survey consequently led to the identification of the different types of receptors and their characterization.

Based on the 2011 site-specific survey, the following five types of receptors[12] have been identified:

- Non-farm residents;
- Farm residents;
- Mennonite farm residents;
- Dairy farm residents; and,
- Industry workers.

While industry workers are all adults, the resident receptor groups will include different age classes. The age class affects the resident's habits, intake rates and dose coefficients, which are used for dose calculations. In this ERA, residents were categorized into three age classes [21] as defined in CSA N288.1-14 [31], i.e., adult, child, and infant.

The locations of the receptors are shown in Figure 3-1. The general characteristics of the receptors are provided in Table 3-2.

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[11] The survey could be carried out more frequently if a significant change occurs in the community and the surrounding area, or if the site operations necessitates an earlier update.

[12] From the perspective of radiological risk assessment, a human receptor is defined as a representative person or "potential critical group", which is defined by the International Commission on Radiological Protection (ICRP) as "the group or groups of people that are thought most likely to receive the largest exposure for a particular site and scenario" [2]. These concepts are used in this report interchangeably.

Figure 3-1: Potential Critical Groups

Table 3-2: Identification of Human Receptors for the HHRA

Receptor Group		General Characteristics of Receptors
Non-farm residents	BR1	Non-farm resident, Lakeshore Scott Point, Located north of the Bruce nuclear site
	BR17	Non-farm resident, Inland, Located to the east of the Bruce nuclear site
	BR25	Non-farm resident, Inland Located to the southeast of the Bruce nuclear site
	BR27	Non-farm resident, Inland, Trailer Park Located to the south of the Bruce nuclear site
	BR32	Non-farm resident, Lakeshore Located to the south of Bruce nuclear site in Inverhuron
	BR48	Non-farm resident, Inland Located to the east of the Bruce nuclear site near Baie du Doré
Farm residents	BF8	Agricultural, farm resident Located to the southeast of the Bruce nuclear site
	BF14	Agricultural, farm resident Located to the southeast of the Bruce nuclear site
	BF16	Agricultural, farm resident Located to the east of the Bruce nuclear site
Mennonite farm residents	BMF2	Agricultural, farm resident Located to the southeast of the Bruce nuclear site
	BMF3	Agricultural, farm resident Located to the southeast of the Bruce nuclear site
Dairy farm residents	BDF9	Agricultural, dairy farm resident Located to the southeast of the Bruce nuclear site
Industry workers	BEC	Worker in BEC (now known as Bruce Eco-Industrial Park) Located to the east of the Bruce nuclear site

There are also some aboriginal communities in the Bruce Peninsula. In this assessment, the aboriginal community members are considered under the category of off-site members of the public. They are further discussed in Section 3.1.3.

3.1.2.2 Receptor Characterization

Food and Water Consumption

The 2011 Bruce Power's site specific survey identified the characteristics of different receptors, specifically consumption of home grown produce and the use of local water supplies [21].

The receptors' average use of home grown or locally grown produce in each food category was determined based on the values reported by respondents. The sum of home grown and locally grown produce consumed is used to represent the food sources which were assumed to be affected by the emissions from the Bruce nuclear site.

Various sources of water used for drinking, bathing, livestock watering and irrigation are identified in the survey; these sources include private wells, community wells and lake water, as well as bottled water, ponds, cisterns, and municipal water. The receptors' average use of each water source was determined based on the values reported by respondents. It is assumed that all sources of water except bottled water were potentially affected by the emissions from Bruce nuclear site.

Exposure Duration and Frequency

For the purposes of the HHRA, it is assumed that all the receptors, except for the Bruce Eco-Industrial Park workers, spend 100% of their time in a single location as shown in Figure 3-1. For the Bruce Eco-Industrial Park workers, they are assumed to have an occupancy factor of 0.23 at their work place (8 hours per day, 5 days per week and 50 weeks per year).

3.1.3 Human Health Exposure Pathways and Conceptual Model

Radiological and non-radiological materials are released to the environment as a result of operations at the WWMF. Consequently, this could result in the emissions to various media, potentially including air, surface water, soil, sediment, groundwater, and other media such as vegetation. Receptors could be exposed to contamination through the following pathways:

- Air inhalation/skin absorption;
- Air immersion (external exposure);
- Water ingestion;
- Water immersion (via swimming or bathing);
- Soil external exposure;
- Soil ingestion (incidental);
- Terrestrial plant ingestion;
- Terrestrial animal ingestion;
- Aquatic plant ingestion;
- Aquatic animal ingestion;

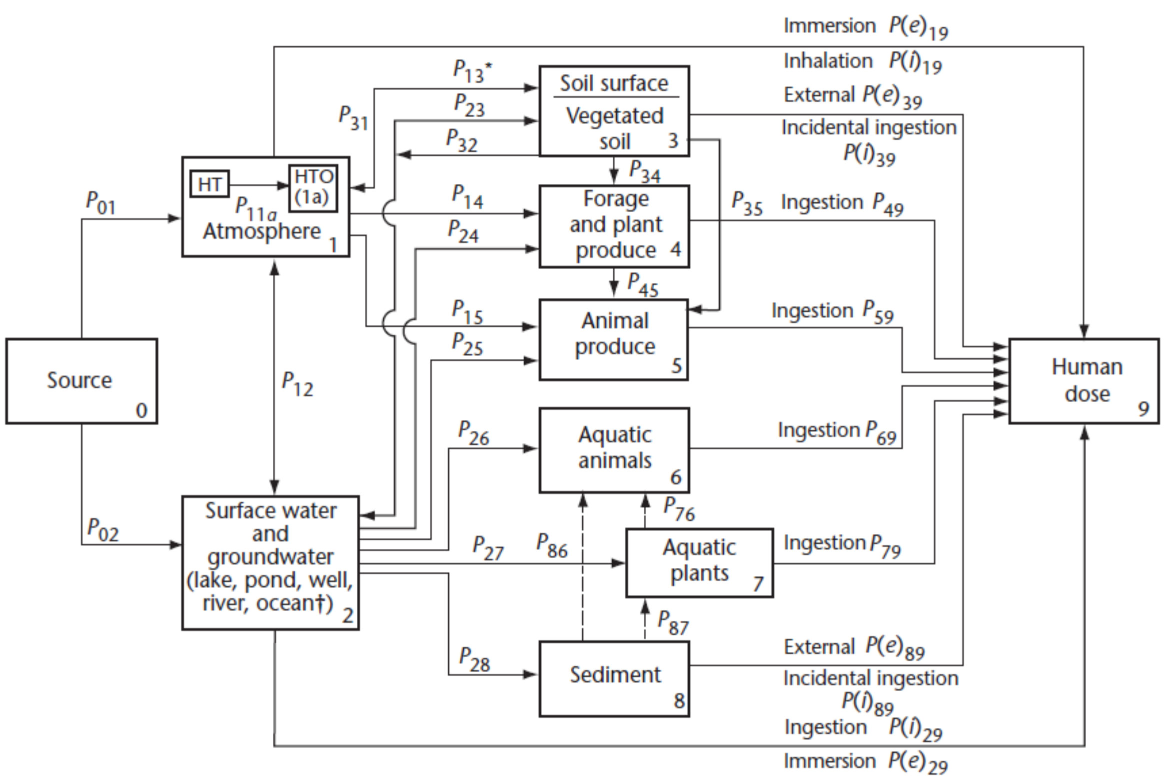
- Sediment external exposure; and,
- Sediment ingestion (incidental).

A generalized model of environmental radioactivity transport and human exposure pathways is shown in Figure 3-2.

Using the concept of compartments, each environmental source/receptor is presented as a numbered compartment. The quantity in compartment i is denoted by X_i. Transfer from compartment i to compartment j is characterized by a transfer parameter P_{ij}. The amount present in compartment j under steady-state conditions due to transfer from compartment i to compartment j is therefore $P_{ij}X_i$. The magnitude of the quantity (concentration or dose) represented by any compartment j is therefore

$$X_j = \sum_i P_{ij} X_i$$

where the summation is over all compartments i transferred into compartment j. Detailed information about the compartments and transfer parameters are provided in CSA N288.1-14 [31].



*Includes transfer factors P_{13area}, P_{13mass}, and P_{13spw}.
†For ocean water, pathways P_{23}, P_{24}, P_{25}, and $P(i)_{29}$ are not used.

Figure 3-2: Environmental Transfer Model [31]

3.2 Assessment of Radiological Impact

Radiological materials could be released to the environment as a result of operations at the WWMF. In this section, the impacts of radiological contaminants on human health are assessed at the PQRA (Tier 2) level.

3.2.1 Selection of Radiological Contaminants

As the result of WWMF operations, airborne and waterborne radioactive materials are released to the environment, as shown in Table 3-3.

Table 3-3: Radiological Emissions from the WWMF

Category of emissions	Radionuclides or radionuclide groups
Airborne emissions	• Tritium Oxide • Particulates • Carbon-14 • I-131
Waterborne emissions	• Tritium Oxide • Gross Beta/Gamma

The assessment of the impact of radiological emissions on human health is presented below.

3.2.2 Radiological Criteria for HHRA

The CNSC has set regulatory limits for exposure to workers and members of the public to ensure that the probability of occurrence of effects is acceptably low [34]. In this assessment, the regulatory limit established to protect members of the public, i.e. an effective dose of 1 mSv per year, will be used as the criterion for the assessment of the impact of radiological contaminants on human health.

3.2.3 Dose to Off-Site Receptors due to External Exposure

Off-site receptors could receive radiation doses from external exposure to gamma radiation from the waste storage facilities at the WWMF and internal exposure through pathways such as consumption of locally-sourced food and water. The external dose rates at the boundary of the WWMF are measured with the Thermoluminescent Dosimeters (TLD) installed around the WWMF fence line. The external dose rates to members of the public were assessed using the TLDs installed around the WWMF fenceline in combination with TLDs located at the Bruce Power indicator sites, which are located closest to the site boundary, as part of the Bruce Power EMP. TLDs provide a measurement of gamma radiation from all sources in the environment. This includes both background radiation and radiation from all anthropogenic sources on the Bruce nuclear site.

As shown in Table 3-4, the average dose rate measured quarterly at the boundary of the WWMF ranges from 0.061 µGy/h to 0.075 µGy/h from 2009-2013 and the maximum dose rate for the same period is 0.155 µGy/h ([35] to [54]). As radioactivity falls off with distance, the external dose from the WWMF is not a significant contributor to public dose and as such, did not carry through into the dose assessment for offsite receptors. This is confirmed with the external gamma measurement taken as part of the Bruce Power EMP ([23], [24], [25], [26], [27]).

Table 3-4: Gamma Dose Rate at the WWMF Fence Line Measured with TLD

Period	Average Dose Rate (µGy/h)	Maximum Dose Rate (µGy/h)
2009 Q1	0.061	0.137
2009 Q2	0.071	0.155
2009 Q3	0.065	0.144
2009 Q4	0.071	0.15
2010 Q1	0.067	0.145
2010 Q2	0.068	0.138
2010 Q3	0.067	0.135
2010 Q4	0.067	0.136
2011 Q1	0.068	0.127
2011 Q2	0.068	0.122
2011 Q3	0.067	0.123
2011 Q4	0.073	0.123
2012 Q1	0.075	0.13
2012 Q2	0.075	0.131
2012 Q3	0.067	0.119
2012 Q4	0.069	0.116
2013 Q1	0.074	0.136
2013 Q2	0.061	0.103
2013 Q3	0.065	0.112
2013 Q4	0.065	0.108

TLDs located throughout Ontario show the average of background radiation levels from 2009-2013 was 0.058 ± 0.014 µGy/h (average ± 2SD). In comparison, the Bruce Power indicator sites (three locations at the Bruce site boundary) show average external gamma dose in air of 0.052 ± 0.006 µGy/h. This demonstrates that the external dose at the closest off-site locations to the Bruce site is no different than background values. As such, the external dose to members of the public from anthropogenic sources on the Bruce Nuclear site (including the WWMF) is considered negligible. Therefore, the following assessment will be focused on the internal exposure of the public due to emissions to air and water.

3.2.4 Doses to Potential Critical Groups Resulting from Other Pathways

The EMP carried out by Bruce Power covers a 20 km radius from the Bruce nuclear site. The monitoring results from this program were used to assess the effect of the operations of all facilities at the Bruce nuclear site.

As part of Bruce Power's EMP, annual public dose resulting from the operation of nuclear facilities at the Bruce nuclear site is determined for each potential critical group located in the vicinity, and for three age classes within each potential critical group (adult, child and infant). The highest dose across all potential critical groups and age classes is designated as the official site dose. The public dose calculation is performed using approved modeling software known as IMPACT[13] and is based on both emissions data and environmental monitoring data, while taking into account the most recent site specific survey results and site meteorological data. Table 3-5 provides the annual Bruce Power site public doses and associated critical groups from 2009-2013 ([23] to [27]).

Table 3-5: Dose to Critical Groups for the Bruce Nuclear Site, 2009-2013

Year	Critical Group	Committed Effective Dose (μSv/y)	Percentage of Regulatory Limit
2009	BF14 Adult	4.4	0.4%
2010	BF14 Adult	2.9	0.3%
2011	BF14 Adult	1.5	0.2%
2012*	BF14 Adult	0.6	0.06%
2012	BMF3 Infant	1.2	0.1%
2013*	BF14 Adult	0.6	0.06%
2013	BMF3 Infant	1.3	0.1%

* For the purpose of comparison, the estimated dose to BF14 adult who was not the critical group for year 2012 and year 2013 are also presented.

From Table 3-5, adults at BF14 were the critical group for the period of 2009-2011. The doses they received ranged from 1.5 μSv/y to 4.4 μSv/y. From 2012 to 2013, infants at BMF3 were identified as the critical group, receiving doses of 1.2 μSv/y to 1.3 μSv/y. The locations of BF14 and BMF3 relative to WWMF are shown in Figure 3-3. Further analysis indicated that for an adult at BF14, the major dose contributors are C-14, tritium and noble gases. They received most of their dose through the

[13] IMPACT is a customizable tool that allows the user to assess the transport and fate of contaminants through a user-specified environment. It also enables the quantification of the human exposure to those radionuclides. The code was developed based on CSA N288.1-08 [73] and has been accepted by the CNSC for public dose calculation.

consumption of food, inhalation and exposure to air [24]; for the infant at BMF3, the major dose contributors are C-14 and radioiodine and the infant received most of its dose through consumption of milk [27].

Figure 3-3: Relative Location of Critical Groups to the WWMF, 2009 to 2013

The maximum dose received by the off-site members of the public presented above, taking into account all potential pathways, is due to the total emissions from all nuclear facilities at the Bruce nuclear site. As shown in Section 2.2.9, the radiological emissions from the WWMF account for a small fraction of the total emissions. On this basis, it was estimated that dose to the critical group of the public due to the operation of WWMF was less than 0.2 μSv/y. This is four orders of magnitude less than the assessment criterion of 1000 μSv/y [34]. Therefore, it can be concluded that there are no radiological effects to the public due to the operation of WWMF, and there is no radiological risk posed to off-site human receptors.

3.2.5 Aboriginal Peoples

There are aboriginal communities in the vicinity of Bruce nuclear site. For example, Historic Saugeen Métis Community is located at the mouth of the Saugeen River in Southampton (25 km north on Lake Huron). The two closest First Nations groups in the vicinity of the Bruce nuclear site [32] are the Chippewas of Saugeen First Nation (25 km north on Lake Huron) and the Chippewas of Nawash Unceded First Nation (70 km north of the Bruce nuclear site). For the purposes of the HHRA, Aboriginal community members were not identified as a specific receptor group. The rationale is provided below.

The potential dose received by any individual is dependent on both the environmental concentration of radionuclides and the habits of potential critical groups. A comparison has been conducted between a representative individual within an Aboriginal group and an adult member of BF14, who is the most highly exposed member of the public for the period of 2009-2011 [33]. The comparison indicated that the concentrations of radionuclides in air, water and foodstuff at the nearest Aboriginal communities (which were located further than BF14) were expected to be lower than those at BF14 due to dispersion and dilution. For example, it is expected that radionuclide concentrations in terrestrial foodstuff consumed by a member of the Aboriginal communities will be at least an order of magnitude below those at BF14. Also it has been shown that the concentration of tritium in fish caught in Georgian Bay is 4 times lower than that modelled in the intake of a BF14 adult; the Carbon-14 concentration is slightly higher in Georgian Bay fish but within 10% of the BF14 adult's exposure. Tritium is the dominant radionuclide for fish ingestion. Therefore, it was concluded that the total dose to a member of an Aboriginal community is expected to be less than that received by the BF14 adult.

For the period of 2012 to 2013, the infant at BMF3 was the critical group [26], [27]. The total dose to a member of the Aboriginal communities is expected to be less than for the infant at BMF3 in this period for the same reasons as the comparison against the BF14 adult in 2009-2011.

Therefore, it can be concluded that individual doses to members of Aboriginal communities are bounded by doses to members of the critical groups identified. Accordingly, the selected human receptors as discussed in Section 3.1.2.1 are considered appropriate for the purpose of HHRA.

3.3 Assessment of Non-Radiological Impact

Non-radiological materials could be released to the environment as a result of operations at the WWMF. In this section, the impacts of non-radiological contaminants on human health are assessed at the screening level (Tier 1) first. The PQRA (Tier 2 assessment) will be carried out, if necessary based on the results of the Tier 1 assessment.

3.3.1 Screening Criteria

The non-radiological substances in different environmental media, including air, surface water, soil, sediment and groundwater, will be screened to identify COPCs.

The screening criteria are applicable federal or provincial human health based guidelines. The guidelines used will be specified in the following screening processes.

3.3.2 Air

Non-radiological substances, such as Nitrogen Oxides (NO_X), Particulate Matter (PM), Carbon Monoxide (CO), Volatile Organic Compounds (VOCs), Trace Metals, and Dioxins & Furans, could be released to air as the result of operation of the facilities at the WWMF. The airborne emission sources have been identified at the WWMF, as listed below [55]:

- Incinerator main stack;
- Lime silo filer vent;
- Incinerator building truck bay roof exhaust;
- Incinerator building HEPA filter exhaust;
- UFDSB active ventilation stack;
- UFDSB drain plug welding;
- UFDSB paint bay vent;
- Transportation package maintenance building ;
- Incinerator emergency vent; and,
- Laboratory QA/QC fume hood[14].

To assess the airborne emissions of non-radiological COPCs from the WWMF, a series of modelling and calculations of airborne emissions have been conducted as documented in WWMF Emissions Summary and Dispersion Modelling Report ([55], [56], [57]). In these reports, the emissions from various sources were estimated based on field measurements and then compared against the emission threshold[15] values which were calculated using the following equation in accordance with Section 8 of O. Reg. 419/05 Air Pollution – Local Air Quality [58]:

Emission Threshold (g/s) = [0.5 x MOE POI Limit] / [Dispersion Factor]

Those contaminants which have the emission rates below the emission threshold are screened out as negligible. Those which did not meet their respective threshold were further assessed.

Based on the most recent Emissions Summary and Dispersion Modelling report [55], most airborne substances emitted from the sources at the WWMF, including sulphur dioxide and dioxins and furans, were screened out using the method discussed above. In addition, airborne emissions of PCBs were well below the threshold, and they were

[14] The fume hood is located at the SSTF, which is no longer operational. It is listed here for completeness.

[15] The dispersion factors were chosen based on the distance to the OPG-retained land property line on which the WWMF is situated, from the source and the averaging period.

not detected in other media at measurable concentrations. There are only three contaminants that were not screened out as negligible:

- Nitrogen oxides (NO_X);
- Hydrogen chloride (HCl); and,
- Chromium VI (Cr(VI)).

For these contaminants, the maximum POI concentrations were calculated for the averaging periods of 1-hour, 24-hour and one year. The calculations are based on the operating conditions, including start-up and shut-down, where all significant sources are operating simultaneously at their individual maximum rates of production. The maximum emission rates for each significant contaminant emitted from the significant sources were calculated in accordance with s. 11 of O. Reg. 419/05. The estimated maximum POI concentrations are presented in Table 3-6.

The calculated maximum POI concentrations were then compared against criteria listed in the ministry publication Summary of Standards and Guidelines to Support Ontario Regulation 419/05: Air Pollution – Local Air Quality [59]. As shown in Table 3-6, all non-radiological substances are well below MOE's POI limits, and are therefore negligible, and not assessed further. Therefore, no non-radiological airborne substances have been identified as COPCs for further assessment.

Table 3-6: Non-Radiological Airborne Emissions and Concentration Estimates

Parameter	Range of Total Emissions (g/s) 2009-2013	Maximum Total Emissions (g/s)	Emission Threshold (g/s)	Max POI Concentration (µg/m³)	Averaging Period	MOE POI Limit (µg/m³)	Limiting Effect	% of MOE POI Limit	Carry Forward to Tier 2
NO_X	$4.28x10^{-2}$	$4.28x10^{-2}$	-	13.2	½-hour	500	Health	3%	No
	$4.63x10^{-1}$	$4.63x10^{-1}$	$3.64x10^{-2}$	92.8	1-hour	400	Health	23%	No
	$1.85x10^{-1}$	$1.85x10^{-1}$	$4.55x10^{-2}$	12.4	24-hour	200	Health	6%	No
HCl	$4.13x10^{-3}$ - $8.04x10^{-2}$	$8.04x10^{-2}$	$4.55x10^{-3}$	7.1	24-hour	20	Health	36%	No
				$2.53x10^{+1}$	½-hour	60	Health	42%	No
Cr (VI)	$2.70x10^{-6}$	$2.70x10^{-6}$	$1.59x10^{-7}$	$1.86x10^{-5}$	Annual	0.00014	Health	13%	No
				$4.33x10^{-5}$	Annual	0.00014	Health	31%	No
	$6.00x10^{-7}$ - $1.10x10^{-6}$	$1.10x10^{-6}$	$5.00x10^{-7}$	$7.36x10^{-5}$	24-hour	0.0007	Health	11%	No
				$2.65x10^{-4}$	½-hour	0.0022	Health	12%	No

Data obtained from [55], [56], [57], [60].

3.3.3 Surface Water

Screening of non-radiological contaminants in surface water was conducted based on the comparison of environmental concentrations against appropriate screening criteria. The environmental concentration data are based on the results of the following monitoring programs:

- Baseline monitoring for the WWMF Expansion Project; and,
- The WWMF EMP.

The environmental concentrations chosen for the screening assessment were the maximum concentrations observed for each substance from the two monitoring programs. A summary of monitoring data is presented in Appendix G.

The screening criteria are taken from the following sources:

- Health Canada Guidelines for Canadian Drinking Water Quality [61]; and,
- Ontario Drinking Water Quality Standards, Objectives and Guidelines [62].

Note that for the purposes of screening, the guideline values which were chosen represent the most restrictive values from the federal and provincial sources listed above. Where a guideline value was not available from these sources, the US Environmental Protection Agency (US EPA) Regional Screening Levels for Residential Tapwaters were consulted [63]. The screening results are presented in Table 3-7.

It should be noted that the general public has no direct access to on-site surface water. They may be exposed to the surface water from Baie du Doré, the receiving waterbody for WWMF surface water, where a dilution factor of 20 is expected [64]. However, for the purposes of the screening assessment, the on-site concentration data from the field measurements at the WWMF have been used.

As shown in Table 3-7, non-radiological contaminants in surface water are either at non-detectable concentrations, below screening criteria or are substances that are considered not harmful at the measured quantities. Therefore, these contaminants are not assessed further.

Table 3-7: Surface Water Screening – Human Health Risk

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
Hardness ($CaCO_3$)	1.0	370	None required	No further assessment is required	No health effects.	[61]
Total Unionized Ammonia	0.0005	0.017	None required	No further assessment is required	No adverse health effects at levels found in drinking water.	[61]
Total Ammonia-N	0.00001	0.00056	None required	No further assessment is required	No adverse health effects at levels found in drinking water.	[61]
Total Chemical Oxygen Demand	0.004	0.047	NV*	No further assessment is required	No health effects.	
Total Dissolved Solids	10	1080	AO*: ≤ 500	No further assessment is required	Aesthetic objective (AO) based on taste and potential for scaling.	[61]
Total Organic Carbon	0.2	13	NV	No further assessment is required	No health effects.	
Total Phosphorus (inorganic)	0.002	0.014	NV	No further assessment is required	Phosphorous is an essential nutrient which is present at a 98th percentile concentration of 8 mg/L in municipal water sources.	[65]
Total Suspended Solids	1.0	5	NV	No further assessment is required	No health effects.	
Alkalinity	1.0	340	NV	No further assessment is required	No health effects.	

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
Dissolved Chloride (Cl)	1 – 5^	460	AO: ≤ 250	No further assessment is required	AO based on taste and potential for corrosion.	[61]
F1 (C6-C10)	0.025	<0.0125	NV	No further assessment is required	Not detected	
F1 (C6-C10) - BTEX	0.025	<0.0125	NV	No further assessment is required	Not detected	
F2 (C10-C16 Hydrocarbons)	0.1	<0.05	NV	No further assessment is required	Not detected	
F3 (C16-C34 Hydrocarbons)	0.2	<0.1	NV	No further assessment is required	Not detected	
F4 (C34-C50 Hydrocarbons)	0.2	<0.1	NV	No further assessment is required	Not detected	
1,3-Dichloropropene (cis+trans)	0.0005	<0.00025	NV	No further assessment is required	Not detected	
Acetone (2-Propanone)	0.01	<0.005	NV	No further assessment is required	Not detected	
Benzene	0.0002	<0.0001	0.005	No further assessment is required	Not detected	[61] [62]
Bromodichloromethane	0.0005	<0.00025	NV	No further assessment is required	Not detected	

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
Bromoform	0.001	<0.0005	NV	No further assessment is required	Not detected	
Bromomethane	0.0005	<0.00025	NV	No further assessment is required	Not detected	
Carbon Tetrachloride	0.0002	<0.0001	0.002	No further assessment is required	Not detected	[61]
Chlorobenzene	0.0002	<0.0001	0.08 AO: ≤ 0.03	No further assessment is required	Not detected. AO based on odour.	[61][62]
Chloroform	0.0002	<0.0001	NV	No further assessment is required	Not detected	
Dibromochloromethane	0.0005	<0.00025	NV	No further assessment is required	Not detected	
1,2-Dichlorobenzene	0.0005	<0.00025	0.2 AO: ≤ 0.003	No further assessment is required	Not detected. AO based on odour; levels above the AO would render drinking water unpalatable.	[61][62]
1,3-Dichlorobenzene	0.0005	<0.00025	NV	No further assessment is required	Not detected	
1,4-Dichlorobenzene	0.0005	<0.00025	0.005 AO: ≤ 0.001	No further assessment is required	Not detected. AO based on odour; levels above the AO would render drinking water unpalatable.	[61][62]
Dichlorodifluoromethane	0.001	<0.0005	NV	No further assessment is	Not detected	

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
				required		
1,1-Dichloroethane	0.0002	<0.0001	NV	No further assessment is required	Not detected	
1,2-Dichloroethane	0.0005	<0.00025	0.005	No further assessment is required	Not detected	[61][62]
1,1-Dichloroethylene	0.0002	<0.0001	0.014	No further assessment is required	Not detected	[61][62]
cis-1,2-Dichloroethylene	0.0005	<0.00025	NV	No further assessment is required	Not detected	
trans-1,2-Dichloroethylene	0.0005	<0.00025	NV	No further assessment is required	Not detected	
1,2-Dichloropropane	0.0002	<0.0001	NV	No further assessment is required	Not detected	
cis-1,3-Dichloropropene	0.0003	<0.00015	NV	No further assessment is required	Not detected	
trans-1,3-Dichloropropene	0.0004	<0.0002	NV	No further assessment is required	Not detected	
Ethylbenzene	0.0002	<0.0001	0.14 AO: 0.0016	No further assessment is required	Not detected. AO based on odour threshold.	[61]
Ethylene Dibromide	0.0002	<0.0001	NV	No further assessment is	Not detected	

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
				required		
Hexane	0.001	<0.0005	NV	No further assessment is required	Not detected	
Methylene Chloride	0.002	<0.001	0.05	No further assessment is required	Not detected	[61][62]
Methyl Isobutyl Ketone	0.005	<0.0025	NV	No further assessment is required	Not detected	
Methyl Ethyl Ketone	0.01	<0.005	NV	No further assessment is required	Not detected	
Methyl t-butyl ether	0.0005	<0.00025	AO: ≤ 0.015	No further assessment is required	Not detected. AO based on odour, considered protective of human health as it would render the water unpalatable and is lower than levels associated with potential toxicological effects.	[61]
Styrene	0.0005	<0.00025	NV	No further assessment is required	Not detected	
1,1,1,2-Tetrachloroethane	0.0005	<0.00025	NV	No further assessment is required	Not detected	
1,1,2,2-Tetrachloroethane	0.0005	<0.00025	NV	No further assessment is required	Not detected	
Tetrachloroethylene	0.0002	<0.0001	0.03	No further assessment is	Not detected	[61][62]

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
				required		
Toluene	0.0002	<0.0001	0.06 AO: 0.024	No further assessment is required	Not detected. AO based on odour threshold.	[61]
1,1,1-Trichloroethane	0.0002	<0.0001	NV	No further assessment is required	Not detected	
1,1,2-Trichloroethane	0.0005	<0.00025	NV	No further assessment is required	Not detected	
Trichloroethylene	0.0002	<0.0001	NV	No further assessment is required	Not detected	
Vinyl Chloride	0.0002	<0.0001	0.002	No further assessment is required	Not detected	[61][62]
p+m-Xylene	0.0002	<0.0001	NV	No further assessment is required	Not detected	
o-Xylene	0.0002	<0.0001	NV	No further assessment is required	Not detected	
Xylene (Total)	0.0002	0.0001	0.09 AO: 0.02	No further assessment is required	AO is based on odour threshold.	[61]
Trichlorofluoromethane	0.0005	<0.00025	NV	No further assessment is required	Not detected	

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
Chromium (+3)F	0.005	<0.0025	NV	No further assessment is required	Not detected; this is an essential element. Chromium levels are protective of effects from Chromium (VI).	[61][62]
Dissolved (0.2u) Aluminum (Al)	0.005	0.023	NV	No further assessment is required	No consistent evidence that aluminum in drinking water causes adverse effects in humans.	[61]
Chromium (VI)F	0.0005	<0.00025	0.05	No further assessment is required	Not detected	[61][62]
Mercury (Hg)	0.00001	0.00002	0.001	No further assessment is required		[61][62]
Dissolved Mercury (Hg)	0.00001	<0.000005	0.001	No further assessment is required	Not detected	[61][62]
Dissolved Calcium (Ca)	0.2	100	None required	No further assessment is required	No evidence of adverse health effects in drinking water.	[61]
Dissolved Chromium (Cr)	0.005	<0.0025	0.05	No further assessment is required	Not detected	[61][62]
Dissolved Magnesium (Mg)	0.05	32	None required	No further assessment is required	Naturally occurring; no evidence of adverse health effects.	[61]
Total Aluminum (Al)	0.0005 – 0.0025^	0.56	NV	No further assessment is required	No consistent evidence that aluminum in drinking water causes adverse effects in humans.	[61]

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
Total Antimony (Sb)	0.00002 – 0.0001^	0.00068	0.006	No further assessment is required		[61][62]
Total Arsenic (As)	0.00002 – 0.00011^	0.001	0.01	No further assessment is required		[61]
Total Barium (Ba)	0.00002 – 0.00012^	0.0505	1	No further assessment is required		[61]
Total Beryllium (Be)	0.00001 – 0.00005^	0.00005	0.0008	No further assessment is required		[63]
Total Bismuth (Bi)	0.000005 - 0.000025^	<0.000025	NV	No further assessment is required	Not detected	
Total Boron (B)	0.05 – 0.25^	0.25	5	No further assessment is required		[61][62]
Total Cadmium (Cd)	0.000005 - 0.000025^	0.000016	0.005	No further assessment is required		[61][62]
Total Calcium (Ca)	0.05	95.23	None required	No further assessment is required	No evidence of adverse health effects in drinking water.	[61]
Total Cesium (Cs)	0.00005 - 0.00025^	<0.00025	NV	No further assessment is required	Not detected	
Total Chromium (Cr)	0.0001 – 0.0005^	0.002	0.05	No further assessment is required		[61][62]

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
Total Cobalt (Co)	0.000005 - 0.000025^	0.001	0.0012	No further assessment is required		[63]
Total Copper (Cu)	0.00005 - 0.00025^	0.005	AO: ≤ 1.0	No further assessment is required	Essential element; adverse health effects occur at levels much higher than the AO. Aesthetic objective based on taste.	[61]
Total Iron (Fe)	0.001 – 0.005^	1.44	AO: ≤ 0.3	No further assessment is required	AO based on taste. No evidence exists of dietary iron toxicity in the general population.	[61]
Total Lead (Pb)	0.000005 - 0.000025^	0.0023	0.01	No further assessment is required		[61][62]
Total Lithium (Li)	0.0005 – 0.0025^	0.003	0.008	No further assessment is required		[63]
Total Magnesium (Mg)	0.05	30.1	None required	No further assessment is required	Naturally occurring; no evidence of adverse health effects.	[61]
Total Manganese (Mn)	0.00005 - 0.00025^	0.32	AO: ≤ 0.05	No further assessment is required	AO based on taste.	[61]
Total Mercury (Hg)	0.00001 – 0.00005^	0.00005	0.001	No further assessment is required		[61][62]
Total Molybdenum (Mo)	0.00005 - 0.00025^	0.00109	0.02	No further assessment is required		[63]
Total Nickel (Ni)	0.00002 - 0.0001^	0.006	0.04	No further assessment is		[63]

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
				required		
Total Phosphorus (P)	0.002 – 0.01^	0.29	NV	No further assessment is required	Phosphorous is an essential nutrient which is present at a 98th percentile concentration of 8 mg/L in municipal water sources.	[65]
Total Selenium (Se)	0.00004 - 0.0002^	0.002	0.01	No further assessment is required		[62]
Total Silicon (Si)	0.1 – 0.5^	4.31	NV	No further assessment is required	Silicon is a basic nutrient in water and is observed naturally from the breakdown of silicate minerals in the process of weathering. Large amounts of silicon are present in surface water.	
Total Silver (Ag)	0.000005 - 0.000025^	0.000025	None required	No further assessment is required	Naturally occurring; drinking water contributes negligibly to daily intake.	[61]
Total Strontium (Sr)	0.00005 - 0.00025^	3.58	480	No further assessment is required		[63]
Total Thallium (Tl)	0.000002 - 0.00001^	0.000012	0.000024	No further assessment is required		[63]
Total Tin (Sn)	0.0002 – 0.001^	<0.001	NV	No further assessment is required	Not detected	
Total Titanium (Ti)	0.0005 – 0.0025^	0.0087	NV	No further assessment is required	Titanium is present at a 98th percentile concentration of 4.8 µg/L in municipal water sources with a maximum concentration of	[65]

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
					10.5 µg/L.	
Total Tungsten (W)	0.00001 - 0.00005^	0.000039	NV	No further assessment is required	Tungsten does not exceed the Provincial water quality objective of 30 µg/L, which is considered protective of recreational water use. Concentrations also do not exceed a groundwater action level of 15 ppm established by Massachusetts.	[66]
Total Uranium (U)	0.000002 - 0.00001^	0.00109	0.02	No further assessment is required		[61][62]
Total Vanadium (V)	0.0002 - 0.001^	0.0012	0.0172	No further assessment is required		[63]
Total Zinc (Zn)	0.0001 - 0.0005^	0.10	AO: ≤ 5.0	No further assessment is required	AO based on taste.	[61]
Total Zirconium (Zr)	0.0001 - 0.0005^	<0.00087	NV	No further assessment is required	Not detected	
Total Sodium (Na)	0.05 – 0.25^	297	AO: ≤ 0.015	No further assessment is required	AO based on taste.	[61]
Total Sulphur (S)	3 – 15^	15	NV	No further assessment is required	Sulphur is present in water as sulphate and sulphide. Sulphate has an AO ≤ 500 mg/L. Sulphide has an AO in drinking water of ≤0.05 mg/L; however, the on-site surface water is not used for drinking. Furthermore, sulphide in	[67][68]

Parameter	Detection Limit (mg/L)	Max concentration (mg/L)	Screening Criteria (mg/L)	Assessment Results	Note	References
					aqueous solution is not stable and will eventually oxidize to sulphate. Therefore sulphate and sulphide are not considered to present a concern.	
Total Potassium (K)	0.04	8.61	NV	No further assessment is required	Potassium is an essential nutrient. Its use as a water softener can result in treated tap water having concentrations up to 8 mg/L.	
Total Thorium (Th)	0.0001	<0.0000001	NV	No further assessment is required	Not detected	

*AO – Aesthetic Objective
NV – No Value
^indicates multiple RDLs applied by analytical lab.

3.3.4 Soil

The general public has no direct access to on-site soil at the WWMF. Therefore, it is unlikely that off-site human receptors will come into contact with non-radiological substances in soil. This exposure pathway is incomplete, and therefore there is no risk to off-site human receptors.

Off-site soil could potentially become affected by WWMF operations due to non-radiological airborne emissions as the airborne contaminants could potentially deposit to ground. However, the results of the screening assessment for airborne COPCs (Table 3-6) show very low concentrations of airborne COPCs which represent a small fraction of MOECC POI limits. Furthermore, there will be significant dilution due to air dispersion before the airborne contaminants deposit to the location where off-site receptors reside. Therefore, it is expected that the contamination of off-site soil resulting from the airborne emissions is negligible.

As such, it can be concluded that the risk to the off-site human receptors associated with exposure to non-radiological contaminants in soil is considered negligible.

3.3.5 Sediment

The general public has no direct access to on-site sediment at the WWMF. Therefore, it is unlikely that off-site human receptors will come into contact with non-radiological substances in sediment. This exposure pathway is incomplete, and therefore there is no risk to off-site human receptors.

3.3.6 Groundwater

The general public have no direct access to on-site groundwater. Therefore, the direct impact to off-site human health of non-radiological substances in groundwater at the WWMF is unlikely.

There is a potential that the groundwater from the WWMF would migrate to surface water (Lake Huron). As discussed in Section 2.2.3, there are two main water-bearing units beneath the WWMF and the expansion areas based on the current conceptual model for groundwater flow at the WWMF: the Middle Sand Aquifer and the carbonate bedrock unit.

Groundwater flow in the Middle Sand Aquifer is towards the east /northeast with respect to geographic north at the rate of between 1 and 50 m/year with a portion of the flow discharging to the SRD through the stormceptor. Downward vertical flow from the Middle Sand Aquifer to the bedrock aquifer occurs, particularly towards the east of the WWMF where the silt tills beneath the Middle Sand Aquifer are thinner. The average linear groundwater velocities estimated within the silty till units are relatively low, of the order of 0.01 to 0.12 m/year, downwards. Groundwater flow within the carbonate bedrock aquifer is horizontal and oriented to the northwest toward Lake Huron, at rates ranging between approximately 10 and 140 m/year. Groundwater discharge occurs at the Lake Huron shoreline approximately 1.4 km from the WWMF [13].

Migration of non-radiological substances in the groundwater before it discharges to Lake Huron is a slow process, during which dispersion and dilution would occur. Furthermore, dilution in Lake Huron at the groundwater discharge point is expected; substances are further diluted at the water intake for the Water Supply Plants in Kincardine and Southampton, which are 15 km SSW of BNGS-B and 22 km NE of BNGS-A, respectively.

Therefore, given the significant dilution which occurs before the substances reach the intake for the Water Supply Plants, additional assessment of the risk associated with non-radiological contamination of on-site groundwater is not warranted.

Off-site groundwater could be potentially affected by airborne contaminants as the contaminants could deposit to the ground and eventually migrate to the groundwater system. However, as discussed in Section 3.3.4, the impact of non-radiological COPCs on off-site soil is negligible. Therefore, it is expected that the potential adverse impact of airborne emissions on off-site groundwater is negligible.

As such, it can be concluded that the risk associated with the public's exposure to non-radiological contaminants in groundwater is considered negligible.

3.3.7 Summary

Based on the screening results, no non-radiological contaminants have been identified as COPCs to be carried forward to a Tier 2 assessment.

3.4 Assessment of Impact of Noise

Noise is the only physical stressor to be considered for the HHRA, which is consistent with CSA N288.6-12 [2]. The results of the assessment are presented below.

3.4.1 Assessment Criteria

The criteria specified in the following document are used for the noise assessment:

- Ontario Ministry of the Environment, "Environmental Noise Guideline Stationary and Transportation Source – Approval and Planning" Publication NPC-300[16], August 2013 [69].

For the purposes of this assessment, the exclusionary noise limits in one-hour equivalent sound level (L_{EQ}, 1 h) for a Class 3 (rural) area at an outdoor point of reception are identified in Table 3-8. With respect to applying the NPC-300 noise criteria in Table 3-8, it is the independent impact of the facility under consideration that is compared to the noise criteria, and not the combined effect of multiple industrial facilities. Therefore, this is typically assessed using the modelled noise impact of a given facility to determine its independent noise impact at a given noise sensitive receptor.

[16] Note that NPC-300 [69] replaces the standard NPC-232, which is referenced in CSA N288.6-12 [2].

Table 3-8: Noise Limits for the Baseline HHRA

Time of Day	Class 3 Area (L_{EQ}, 1 h)
07:00 – 19:00 (daytime)	45 dBA
19:00 – 07:00 (nighttime)	40 dBA

The exclusionary limits defined in Table 3-8 are considered significant impacts when exceeded with respect to community annoyance to noise. They are sufficiently quieter than hearing loss criteria (e.g. 85 dBA), and exceedance of these Table 3-8 noise criteria are not considered an adverse effect to human health.

3.4.2 Assessment Based on Field Measurement

Noise baseline measurements were conducted for a two-week period in May or August 2014 at three off-site locations, including two residential locations: R1 – Albert Road, and R2 – west end of Concession Road 6 across from Baie du Doré[17]. The third location, R3, was within Inverhuron Park.

Noise receptors R1, R2 and R3 have been chosen to reflect the worst-case predicted location for a group of human receptors (typically the closest location to a group of residents). This is different than other disciplines (e.g. radiological components or air quality) that may define their receptors for each residential location due to a dispersion modelling methodology. For the purpose of this assessment, R1 was chosen to reflect human receptors in the Albert and Bruce Road locations, R2 was chosen to reflect human receptors in the Baie du Doré and Concession Road 6 location, and R3 was chosen to reflect human receptors at the Inverhuron Park area. A review of these noise receptors shows that they are representative of worst-case noise impact locations for all human receptors in the area, and this is consistent with the approach taken in previous EAs for noise impact [5], [70].

The monitoring locations are illustrated in Figure 3-4. These are at the noise impact locations R1, R2 and R3 as discussed above.

[17] The additional measurement of noise level at locations on the Bruce nuclear site closer to the WWMF was conducted in 2015. The results are further discussed in Section 4.4.

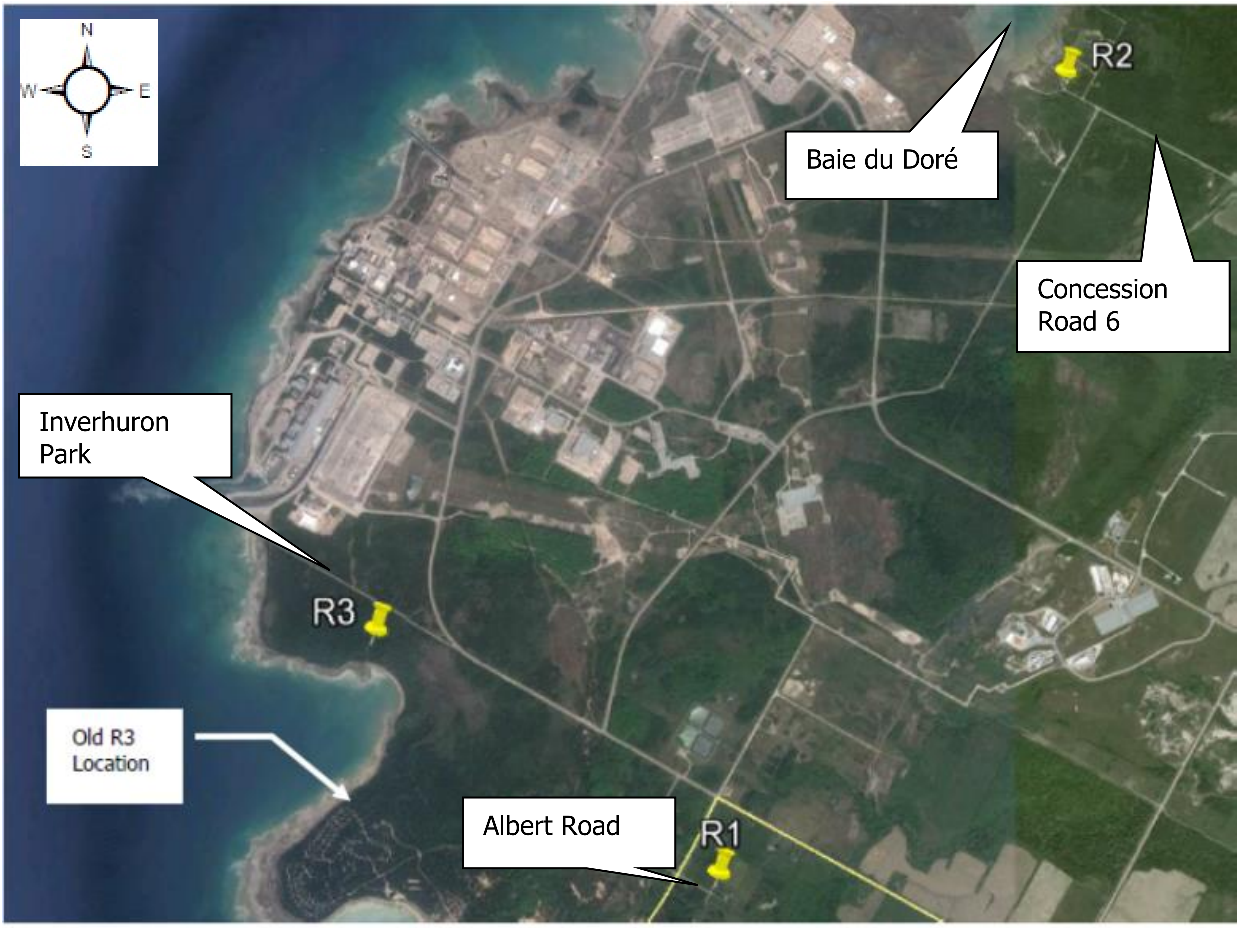


Figure 3-4: Sampling Locations for Noise Baseline Monitoring[18]

For the purposes of the assessment, the maximum one-hour L_{90} noise levels were used to represent the expected noise impact at the receptor locations resulting from the Bruce nuclear site operations. Although the noise criteria are referenced in L_{eq}, it was considered that L_{eq} measurements may be influenced by other environmental factors (lake noise, traffic, other natural sounds), and that the L_{90} would be most representative of noise level due to the operations of facilities at Bruce nuclear site.

[18] Note: "Old R3 location" refers to noise receptor location from previous EAs ([5], [70]). This is provided as reference with respect to field monitoring discussions noted below.

By taking the maximum L_{90}, a conservative assessment of the highest facility generated noise at the receptor locations R1 and R2 was considered[19].

The representative maximum one-hour L_{90} noise levels during the monitoring period are presented in Table 3-9.

Table 3-9: Maximum Noise Values Measured at R1 and R2

Location	Max L_{90}, 1 h (dBA)	Time	Associated Period	Noise Criteria L_{EQ}, 1 h (dBA)
R1 – Albert Road	39.5	12:00 – 13:00	Daytime (07:00 – 19:00)	45
R2 – Baie du Doré	42.2	00:00 – 01:00	Night (22:00-23:00)	40

The measured baseline measurements for location R3 are not presented in Table 3-9. Although noise monitoring was conducted during the same period at R3, it has been omitted from Table 3-9, since the measurements were contaminated by noise from adjacent construction and were considered unusable for the purposes of this assessment. The Inverhuron Park R3 receptor location was moved compared to previous EA R3 locations [5], [70] (noted as "Old R3 Location" in Figure 3-4) to try and accommodate this construction noise, but results were determined to be unusable for the purpose of this assessment.

These results suggest that, based on a conservative noise impact, the current operations at the Bruce nuclear site may be at or above the nighttime noise criteria at R2.

Given the various sources on the Bruce nuclear site, acoustic modelling is required to confirm these noise levels with respect to the current noise impact of the WWMF.

3.4.3 Modelling of Noise Level

3.4.3.1 Noise Modelling

Noise emissions from the Bruce nuclear site were initially documented in Bruce Nuclear Power Plant Project Environmental Assessment EIS Studies Air Quality and

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[19] L_{eq} is an energy average sound level. Whereas noise levels change every second over a period of time, this value is used to provide a representative steady noise level that would have the same acoustic energy as all of the varying noise levels measured in a given period. By its nature, the L_{eq} measurement includes all noise sources at a given location, and the value would not isolate a specific source level unless it dominates the ambient environment. Further, higher transient noises can increase the L_{eq}, giving a false representation of the background noise level. Therefore, it is a common industry practice to use a statistical noise measurement, L_{90}, to characterize the dominant background noise level, as it filters all of the high noise levels out, to give a representation of the underlying ambient sound level in the environment.

Noise Technical Support Document [70]; however, noise measurements have been revised to provide a 2015 noise level reference.

The noise emissions from the existing WWMF were estimated using information from the MOECC's ECA for the facility and the Emissions Summary and Dispersion Modelling Report [57].

The following noise sources were identified at the existing WWMF and were included in the noise prediction model:

- One incinerator stack;
- One silo dust collector;
- Twenty four exhaust/ventilation stacks;
- One emergency generator; and,
- Three idling trucks.

The noise sources were modelled based on the sources listed above. In the absence of WWMF equipment sound power levels, they were estimated based on typical manufacturer's data sheets and/or the database for similarly sized units. The overall sound power levels of the noise sources at the Bruce nuclear site were also considered in the assessment. Table 3-10 provides a noise source summary.

Table 3-10: Noise Source Summary

Noise Source Description	Source ID	Sound Power Level dBA (ref. 10^{-12} Watts)	UTM Coordinates		Height Above Grade (m)
			X	Y	
Incinerator Exhaust Stack	S01	101	453449	4907814	21
Lime Silo Dust Collector	S02	78	453434	4907817	6
Truck Bay Area Exhaust Stack	S03	100	453483	4907810	7
Waste Volume Reduction Ventilation Stack	S04	112	453477	4907798	14
Dry Storage Container Processing Building Exhaust Stack	S05	97	453681	4907819	25
Drain Weld Exhaust Fan	S06	87	453663	4907850	8
Paint Bay Exhaust	S07	109	453661	4907846	12
UFDSB Emergency Generator (Daytime Only)	S08	101	453735	4907819	2
Transport Package Maintenance Building Exhaust Stack	S09	107	453489	4907862	14
SGSB Exhaust 1	S10	93	453639	4907647	1
SGSB Exhaust 2	S11	93	453638	4907673	1
RCSB Exhaust 1	S12	93	453651	4907698	1
RCSB Exhaust 2	S13	93	453672	4907709	1
LLSB Exhaust 01	S14	93	453375	4907919	1
LLSB Exhaust 02	S15	93	453435	4907924	1
LLSB Exhaust 03	S16	93	453406	4907973	1
LLSB Exhaust 04	S17	93	453383	4907945	1
LLSB Exhaust 05	S18	93	453326	4907948	1
LLSB Exhaust 06	S19	93	453356	4907896	1
LLSB Exhaust 07	S20	93	453294	4907894	1
LLSB Exhaust 08	S21	93	453328	4907846	1
LLSB Exhaust 09	S22	93	453343	4907864	1
LLSB Exhaust 10	S23	93	453371	4907807	1
LLSB Exhaust 11	S24	93	453723	4907680	1
LLSB Exhaust 12	S25	93	453692	4907616	1
LLSB Exhaust 13	S26	93	453664	4907728	1
LLSB Exhaust 14	S27	93	453729	4907692	1
WWMF Idling Truck1	S28	98	453519	4907761	2
WWMF Idling Truck2	S29	98	453506	4907916	2
WWMF Idling Truck3	S30	98	453418	4907829	2

Noise Source Description	Source ID	Sound Power Level dBA (ref. 10^{-12} Watts)	UTM Coordinates		Height Above Grade (m)
			X	Y	
Other Bruce nuclear site General Operating Noise Source (Night-time Only)	S32	121	454301	4909830	25
Other Bruce nuclear site Emergency Generator (Daytime Only)	S33	122	454301	4909830	25
Other Bruce nuclear site General Operating Noise Source (Night-time Only)	S34	121	451801	4907565	25
Other Bruce nuclear site Emergency Generator (Daytime Only)	S35	122	451802	4907565	25

The significant noise sources considered in the assessment are shown in Figure 3-5 and Figure 3-6.

Figure 3-5: WWMF Significant Noise Source Locations[20]

[20] Imagery for Figure 3-5, Figure 3-6, and Figure 3-7 obtained from Google Earth Professional [71], map data provided by Land Information Ontario (Ministry of Natural Resources and Forestry).

Figure 3-6: Other Bruce Nuclear Site Noise Source Locations[20]

The current noise impacts from the existing Bruce nuclear site, including the WWMF, on the surrounding human receptor locations was predicted using the Cadna/A software package, published by Datakustik GmbH. The software is configured to implement the ISO 9613-2 environmental noise propagation algorithms [72]. It has been widely accepted for evaluating noise and is an accepted model by the MOECC. The model takes the following factors into account:

- source sound levels;
- source directivity;
- distance attenuation;
- source-receptor geometry including heights and elevations;
- barrier effects of the building and surrounding topography;
- ground and air (atmospheric) attenuation; and
- meteorological effects on noise propagation.

Noise sources are characterized by entering the sound power and/or sound pressure level associated with each source. Other parameters including building dimensions, frequency of use, hours of operation, and enclosure attenuation ratings also define the nature of sound emissions.

The ISO 9613-2 prediction method is conservative as it assumes that all receptors are downwind from the noise source or that a moderate ground based temperature inversion exists. In addition, ground cover and physical barriers, either natural (terrain-based) or constructed and atmospheric absorption are included.

3.4.3.2 Noise Receptors

The receptor locations are described in Table 3-11 and are shown in Figure 3-7. Emergency generator testing is considered for daytime period only (07:00 to 19:00).

Figure 3-7: Noise Receptor Locations[20]

3.4.3.3 Noise Results and Discussion

Baseline measurements completed in 2014 could not isolate the noise influence from the operations at WWMF. Therefore, the noise levels at the receptor locations were modelled to determine the specific impact of the WWMF on the human receptors.

The modelled noise levels as part of this HHRA represent the operational impact from the WWMF and other sources on the Bruce nuclear site. The noise levels modelled from the existing facility noise sources are summarized in Table 3-11.

Table 3-11: Modelled Noise Levels at Receptor Locations Contributed by Existing Facilities

Receptor Description	Receptor ID	Modelled Day/Night Noise Levels L_{EQ}, 1hr dBA	Combined Modelled Day/Night Noise Levels on the Bruce Nuclear Site	MOECC Day/Night Noise Level Limits
		WWMF	L_{EQ},1hr dBA	L_{EQ},1hr dBA
R1 - Albert Street	R1	26/26	31/31	45/40
R2 - Baie du Doré	R2	26/26	42/41	45/40
R3 - Inverhuron Park	R3	25/25	35/34	45/40

The modelled noise levels at the receptor locations from the existing WWMF operation are well below the applicable MOECC NPC-300 noise level limits and meet the acceptable noise criteria for human receptors. The combined modelled noise during nighttime at R2 is higher than the MOECC noise level limit; this suggests that the combined noise from the operations on the Bruce nuclear site may be at or above the nighttime noise criteria at R2, and could potentially be an annoyance to humans. However, based on the modelled results, the WWMF is considered an insignificant contributor to noise at receptor R2.

When modelled noise levels are compared to the baseline measurements completed in 2014 (see Table 3-9), the following can be noted:

a) At receptor R1, the combined predicted noise levels (31/31 dBA) are about 8 dB lower than the measured baseline measurement (39.5 dBA), which indicates that there are other noise sources in the area (e.g., traffic) that may influence the measurements;

b) At receptor R2, the combined modelled noise levels (42/41 dBA) are lower than the measured baseline measurement (42.2 dBA), but not by a significant margin; they are within 1 dB of one another. This suggests that there may be an additional influence on the measurements (e.g. lake) which has about the same noise impact as the predicted noise levels.

As a result, noise modelling completed for the existing conditions at the Bruce nuclear site shows that the noise level from the operation of the WWMF meets the MOECC noise criteria. As such, it can be it can be concluded from the noise modelling results that the current noise levels from WWMF operation pose no adverse effects to human health.

3.5 Risk Characterization

Based on the screening level risk assessment, which takes into account the contamination of different media including air, surface water, soil, sediment, and groundwater, non-radiological contaminants resulting from the operation at the WWMF pose no adverse effects to human health. No additional assessment is required.

For the radiological emissions, the dose to the critical group as the result of operation of all nuclear facilities at the Bruce nuclear site is less than 5 μSv/y, representing approximately 0.5% of the public dose limit. The dose to the critical group of the public due to the operation of the WWMF was estimated to be less than 0.2 μSv/y, four orders of magnitude less than the public dose limit. Therefore, there are no adverse radiological effects to human health due to the operation of the WWMF.

For noise, the analysis of the modelling results shows that noise levels from the operation of the WWMF, are compliant with the NPC-300 for all locations and time periods. Therefore, it can be concluded that the operation of the WWMF poses no adverse effects to human health.

3.6 Uncertainty Associated with Human Health Risk Assessment

Uncertainty could be introduced into the risk assessment during the process of screening, exposure assessment and risk characterization. The uncertainty can be minimized through the analysis of sources and historic trends, along with the use of conservative assumptions throughout the risk assessment, to ensure that human health is protected. A qualitative analysis of the uncertainty associated with the HHRA is presented below.

For the radiological risk assessment, the site monitoring data were used along with the use of modeling results where monitoring data are not available. The computer code used for the dose calculation, including the value of the parameters for the embedded models, is in line with CSA standard N288.1-08 [73]. Furthermore, the calculated doses to the critical group, the highest exposure group, represents only a small percentage of the regulatory dose limit.

The screening of non-radiological contamination is carried out based on the comparison of up-to date site monitoring data and the screening criteria. In this process, the maximum concentrations of non-radiological substances in different media based on field measurement or modelling are used. Specifically, for the screening of non-radiological contaminants in air, the screening approach as described in Section 3.3.2 follows the procedure for preparing an emission summary and dispersion modelling, which was developed by the regulating agency MOECC to ensure the fair and consistent implementation of Ontario Regulation 419/05 Air Pollution – Local Air Quality, made under the Environmental Protection Act [74]. The main source of uncertainty in calculation of emission thresholds is associated with the use of dispersion factors as provided in Table B-1 of MOECC's procedure for preparing an emission summary and dispersion modelling [74]. Dispersion of contaminants can be influenced by a number of factors including; terrain, land use, localized facility layout and localized wind patterns. Locations may not be fully indicative of an urban or a rural land use. As such the dispersion factors presented do not necessarily reflect the site specific dispersion characteristics of the WWMF area. However, the calculation of the emissions threshold is considered conservative and acceptable by the MOECC in conducting an assessment of potential contaminants that may require further modelling assessment at site-specific scale. The uncertainty associated with the screening approach described herein is not expected to appreciably increase the potential for exclusion of important airborne contaminants.

Furthermore, the most restrictive guideline from reputable sources, if applicable, are adopted as the screening criteria for the assessment. This will ensure that the conclusion of the screening assessment is valid, with a high level of confidence.

There is uncertainty in both the noise measurements and the modelling. Sound level monitoring units generally have a measurement error of within +/- 1 dB. For noise modelling, the assessment of source sound levels and the locations of these sources represent the greatest sources of uncertainty. For this assessment, the modelling relied on manufacturer and reference data for the WWMF sources, and the simplified noise source modelling of the Bruce nuclear facilities as provided in previous EAs. The third element of uncertainty in the noise modelling is in the sound propagation methodology and assumptions on wind direction, ground and air absorption, barriers/buildings, reflections and topography. However, the measurements and modelling results are reasonably correlated, and there is conservatism in the modelling; therefore, it is expected that the uncertainty associated with the noise levels has no impact on the conclusions.

In summary, the assessment method and the conservative assumptions used for the HHRA ensure that the actual risks are not underestimated. Therefore, the uncertainty associated with the assessment has no impact on the conclusions of the HHRA.

4.0 Ecological Risk Assessment

4.1 Problem Formulation

4.1.1 Receptor Selection and Characterization

4.1.1.1 Selection of VECs and Indicator Species

It is not practical to assess the radiological or non-radiological dose to each species residing on the Bruce nuclear site at the WWMF and vicinity. For the purpose of the EcoRA, the Valued Ecosystem Components (VECs) were chosen for the WWMF and vicinity, which are elements of the environment that have scientific, economic, social or cultural significance and which may have potential exposure to contaminants due to the operation of the WWMF. VECs were determined based on a review of previous EAs for the DGR and the WWMF ([75], [76]). In addition, any new species identified in the most recent WWMF (and vicinity) site survey have also been considered. The VECs were identified using the expertise of technical specialists from various environmental disciplines, based on the VECs used in previous EAs and ERAs performed for portions of the Bruce nuclear site, which incorporated inputs from regulators and members of the public. Photographs of the WWMF site can be found in Sections 2.2.4.2 and 2.2.5.

However, in order to determine the potential effect of radiological and non-radiological emissions on the environment, a smaller group of indicator species was chosen to represent VECs selected for assessment. Indicator species were chosen based on at least one of the following criteria:

- They are reflective of the main exposure pathways, feeding habits, habitats, etc. on the site, and particularly those associated with the highest exposures;
- They are known to reside on the site, and therefore are potentially exposed to environmental effects from the WWMF;
- Represents a major plant or animal group, they are representative of their trophic level, resulting in representation for all trophic levels and therefore all exposure pathways;
- They are particularly sensitive to stressors;
- They occupy a unique niche in the habitat or have a unique diet;
- They are ecologically significant (e.g., classified as SARs); or,
- They have a special socio-economic importance or value, e.g., due to their economic value or cultural importance.

Indicator species were also chosen based on the result of previous EAs. Table 4-1 shows the comprehensive list of VECs for the WWMF for this EcoRA as well as their indicator species, for which the assessment is conducted.

Note that the assessment of risk to non-human biota is based on the impact to the indicator species on a population or community level, rather than on an individual level. The exception is the assessment of risk to SARs, which are evaluated at an individual level.

Table 4-2 shows a summary of the indicator species chosen to represent the various trophic levels and ecological receptors in the VEC list and for the SARs. This table represents the species for which exposure will be assessed in the Tier 2 assessment. The specific species identified as indicator species are evaluated within the radiological and non-radiological assessments. The evaluation of the indicator species may also be considered protective of another receptor of interest, as discussed in the column "Rationale". The exposure pathways that have been considered for these species are addressed in Section 4.1.2. A detailed description of each indicator species has been provided in Appendix C.

Table 4-1: VECs and Indicator Species for the EcoRA

Class	VEC	Indicator Species	Rationale
Water bodies	Baie du Doré Wetland	Cattails Benthic Invertebrate Community Northern Redbelly Dace Painted Turtle	The Baie du Doré Wetland is a Provincially Significant Wetland. Although the Baie du Doré wetland lies outside the future WWMF, it does partially overlap with the Bruce nuclear site. Protection of aquatic receptor group populations (plants, fish, and invertebrates) is the goal for this VEC. A specific species of interest is the Midland Painted Turtle [77].
	Lake Huron and Embayments	Smallmouth Bass Lake Whitefish	Protection of aquatic receptor group populations (plants, fish, and invertebrates) is the goal for this VEC. Specific species of interest: Lake Whitefish, Salmonids (i.e., Whitefish, Salmon, Brook Trout). Salmonids including Whitefish are of importance to fisheries (Aboriginal, commercial and/or recreational). Salmonids are a sensitive receptor and their health provides an indicator of water quality.
	South Railway Ditch (SRD) and Wetland Complex adjacent to WWMF expansion area (cedar swamp and marsh complex)	Cattails Digger Crayfish Benthic Invertebrate Community Northern Redbelly Dace Northern Leopard Frog	Wetlands are a critical component of the ecosystems, providing multiple functions including flood attenuation, water quality improvement, and potential groundwater recharge and wildlife habitat. Protection of various receptor groups present in wetlands and aquatic environments is the goal for this VEC. Specific species of interest: cattails, Northern Redbelly Dace, Creek Chub and Green Frog. Northern Redbelly Dace are an indicator of small-bodied fish community (productivity). Inhabits SRD, is common in wetland conditions, cool/warm water tolerant, and has an affinity for organic substrates and aquatic vegetation.

Class	VEC	Indicator Species	Rationale
			Creek Chub - Inhabits the SRD, cool water species, tolerant of organic pollution and low dissolved oxygen, and moderately intolerant to turbidity. Green Frogs are an obligate wetland species, spending its entire life within or immediately adjacent to permanent wetlands, it is vulnerable to direct contact with discharges to water. Cattail - major vegetation type in SRD and Wetland, provides bio-remediation properties. As described below, indicator species have been chosen for the specific species of interest in this ERA. For the fish species (Northern Redbelly Dace and Creek Chub), the Northern Redbelly Dace has been chosen as the representative indicator for this assessment. For the Green Frog, the Northern Leopard Frog has been chosen as the representative indicator.
	West Ditch	Cattail Digger Crayfish Benthic Invertebrate Community Northern Redbelly Dace	Protection of aquatic receptor group populations (plants, fish, and invertebrates) is the goal for this VEC. Northern Redbelly Dace are an indicator of the small-bodied fish community (productivity). They inhabit the West Ditch, are common in wetland conditions, cool/warm water tolerant, and have an affinity for organic substrates and aquatic vegetation. Creek Chub are an abundant species within the West Ditch. A cool water species, tolerant of organic pollution and low dissolved oxygen, and moderately intolerant to turbidity. As described below, the Northern Redbelly Dace, has been chosen as the indicator species for both the Northern Redbelly Dace and Creek Chub. Cattail - major vegetation type in the West Ditch, provides bio-remediation properties.

Class	VEC	Indicator Species	Rationale
	Stream C	Cattails Digger Crayfish Benthic Invertebrate Community Northern Redbelly Dace Smallmouth Bass	The Railway Ditch discharges to Stream C which, in turn, discharges into Baie du Doré, a provincially significant wetland. Stream C provides cold water fish habitat (i.e. Brook Trout). Protection of aquatic receptor group populations (plants, fish, and invertebrates) is the goal for this VEC. Specific species of interest: Salmonids (i.e., Brook Trout).
Habitat	Terrestrial Crayfish Habitat	Digger Crayfish	Digger Crayfish is a species of interest to the community based on its limited geographic distribution. Terrestrial crayfish habitats were evaluated as “significant” based on the criteria outlined in the Significant Wildlife Habitat Technical Guide (SWHTG) [78] and the associated criteria schedules. Digger crayfish burrows have been seen on the WWMF during the most recent baseline monitoring surveys. The crayfish have been included as an indicator species due to their status as a species of interest to the community; however, it should be noted that the crayfish are not a SAR.
	Turtle Wintering Habitat	Painted Turtle	Both snapping turtles and painted turtles are present and have wintering habitat in the OPG retained lands, and have been observed in ponds on the WWMF during the most recent baseline monitoring survey. Painted turtles have been chosen as the indicator species for turtles as this species forms the majority of the turtle population on site, based on the most recent survey. Turtle Wintering Habitats were evaluated as “significant” based on the criteria outlined in the SWHTG [78] and the associated criteria schedules.
	Amphibian Woodland	Spring Peeper	Spring Peepers are common on the WWMF, throughout lowland

Class	VEC	Indicator Species	Rationale
	Breeding Habitat		(moist soils) and treed wetland habitats and represent a large component of the biomass within the lower trophic levels. As a terrestrial amphibian, Spring Peepers are more vulnerable than birds and mammals to direct contact with airborne contaminants and changes in soil quality. Since this species lives in terrestrial environments, it is susceptible to road-related mortality. Amphibian Woodland Breeding Habitats were also evaluated as "significant" based on the criteria outlined in the SWHTG [78] and the associated criteria schedules.
	Amphibian Wetland Breeding Habitat	Northern Leopard Frog	Northern Leopard Frogs were common throughout lowland (moist soils) and treed wetland habitats and represent a large component of the biomass within the lower trophic levels. As an amphibian, Northern Leopard Frogs are more vulnerable than birds and mammals to direct contact with airborne contaminants, water discharges and changes in soil quality. Since this species spends the majority of its adult life stage in terrestrial environments, it is susceptible to road-related The Northern Leopard Frog has been identified as the indicator VEC for evaluating the Amphibian Wetland Breeding Habitat. Amphibian Wetland Breeding Habitats were also evaluated as "significant" based on the criteria outlined in the SWHTG [78] and the associated criteria schedules.
Terrestrial Vegetation	Trees	Eastern White Cedar	An abundant tree species in the OPG retained lands. The eastern white cedar is slow growing, and plays an important role in providing conditions that support wildlife habitat and presence of plant species. The eastern white cedar is preferred by white-tailed deer for

Class	VEC	Indicator Species	Rationale
			both shelter and as an important food source in the winter, and is also used by such animals as snowshoe hare, porcupine and red squirrel. As a coniferous plant, the eastern white cedar may be more susceptible to foliar damage from changes in air quality.
	Graminoids (grasses, sedge, and rushes)	Grass	Graminoids are abundant within the Terrestrial Monitoring Study Area (the area that was surveyed in 2014 to characterize the Terrestrial baseline) and are representative of a ground cover species and are chosen to assess the effects associated with vegetation loss and radiological and non-radiological emissions on understory vegetation. Ground cover provides food and shelter for a variety of species and is relevant in the maintenance of a healthy ecosystem.
Aquatic Vegetation	Aquatic Vegetation Community	Cattail	Aquatic vegetation provides a source of shelter and food for aquatic species. It assists in water quality and provides an indication of habitat quality. Common cattail is a native emergent wetland species which grows intermittently in drainage ditches and remnant pools on the OPG retained lands. Cattail is known for its ability to filter wastewater, which may lead to pollutant (including heavy metals) accumulation in the plant tissues. It is used by red-winged blackbird for nesting and by muskrat as a primary food source and as a shelter material. It can be used to assess the effects of both radiological and non-radiological emissions, in particular those to the surface water environment, on vegetation.

Class	VEC	Indicator Species	Rationale
			Tissue samples have been collected.
Terrestrial Invertebrates	Terrestrial Invertebrates	Earthworm	Soil invertebrates such as earthworms, grubs, arthropods, etc. are present on the OPG retained lands. Invertebrates provide a food source to mammals and birds and the community can reflect the health of the environment.
	Insects	Bee	Insects are important to all ecological environments. As pollinators, bees are an ecologically important insect species. They live wherever there are flowers to feed on and are therefore likely present on site. Bees are used as an indicator for flying insects.
Aquatic Invertebrates	Aquatic Invertebrates	Digger Crayfish	Aquatic invertebrates including species living in the water column. Aquatic invertebrates are an important food item for many species of fish and waterfowl. Aquatic invertebrates living in the water column are used in the evaluation of surface water quality. Active crayfish burrows and chimneys have been observed within the WWMF. The Digger Crayfish (*Fallicambarus fodiens*) has been seen on site and is used as an indicator for other crayfish species that may be present on site.
	Benthic Invertebrates	Benthic Invertebrate Community	Aquatic invertebrates living on or in sediment. Aquatic invertebrates are an important food item for many species of fish and waterfowl. Benthic invertebrates are used to provide an indication of habitat quality in the drainage features at the OPG retained lands.
Fish	Inshore and Forage Fish	Spottail Shiner Smallmouth Bass	The Spottail Shiner is common in Lake Huron near shore areas within the study area and is an important source of food for predatory fish and is used as a baitfish by anglers. They are a

Class	VEC	Indicator Species	Rationale
			small minnow species; the indicator species is the Northern Redbelly Dace. The Smallmouth Bass is a warm water near shore species in Lake Huron. The species is important to the recreational fishery and feeds on several trophic levels as an omnivore (benthic invertebrates, crayfish, and fish). The species is sensitive to changes in near shore habitat (physical, chemical and thermal).
	Offshore Fish	Lake Whitefish Deepwater Sculpin	Lake Whitefish is an important species to commercial, recreational and Aboriginal fisheries. The Lake Whitefish has been chosen as the indicator species, given its relevance to the commercial fisheries. Deepwater Sculpin is a threatened species and of special concern in the Great Lakes. These indicator species have been included in order to assess the potential impact of surface water contaminants from the WWMF on species in Lake Huron, as surface water can migrate offsite.
Herpetofauna	Snake	Northern Water Snake	The northern water snake was most recently documented within the SRD in September 2013. Northern water snakes can be found in and around almost any permanent body of fresh water, rarely occurring far from shore. The northern water snake is an important component of the aquatic and adjacent terrestrial ecosystems as it preys on fish and amphibians.
	Frogs	Northern Leopard Frog	See Amphibian Wetland Breeding Habitat
		Spring Peeper	See Amphibian Woodland Breeding Habitat
	Turtles	Painted turtle	See Turtle Wintering Habitat

Class	VEC	Indicator Species	Rationale
Birds	Red-eyed Vireo	Red-eyed Vireo	Red-eyed vireo is one of the most common species in the Terrestrial Monitoring Study Area and is representative of a forest dwelling bird species. Habitat typically consists of large expanses of deciduous forest; however, this species is not area sensitive and frequently inhabits small forest fragments with mature deciduous trees. It is insectivorous and gleans insects (mainly caterpillars) off leaves and bark in the sub-canopy and canopy of trees.
	Wild Turkey	Wild Turkey	Wild turkey is a territorial omnivorous ground dwelling bird using deciduous forest habitat near open communities. Wild turkey is an important subsistence, cultural and recreational feature of the study areas that was nearly extirpated from Canada because of unrestrained hunting and habitat loss, but has been successfully re-established in southern Ontario through Ministry of Natural Resources and Forestry reintroduction and conservation efforts. This species over-winters within the area of the site (deciduous forest and coniferous swamp). This species can be used to assess the effects of habitat loss on ground dwelling game birds with larger territorial areas as well as noise disturbance associated with traffic, construction equipment, and increased human activity.
	American Robin	American Robin	The American Robin is particularly sensitive to COPCs in soil due to their high ingestion of earthworms. The American Robin has been identified at OPG retained lands. The American Robin lives in a variety of habitats, including woodlands, wetlands, suburbs, and parks. They forage on the ground in open areas, such as meadows or parkland.

Class	VEC	Indicator Species	Rationale
	Mallard	Mallard	The mallard is an omnivorous waterfowl species that has been observed at the Bruce nuclear site, utilizing stable shallow areas for foraging and nesting. This omnivorous species primarily feeds on aquatic vegetation, seeds, acorns and grains, and occasionally on fish and other aquatic organisms. The mallard can be used to assess the effects of airborne and waterborne emissions that may, in turn, influence forage opportunities as well as noise disturbance associated with traffic, construction equipment, and increased human activity.
	Bald Eagle	Bald Eagle	The bald eagle is a carnivorous bird that preferentially eats fish. It has been identified as having a winter population on the Bruce nuclear site. It is considered a socially important species.
Aquatic Mammals	Muskrat	Muskrat	The presence of the muskrat has decreased on the OPG retained lands and is now absent from the Terrestrial Study Area, as previously documented in the DGR EA [5]; however, it is known to be present elsewhere at the Bruce nuclear site. This herbivorous aquatic mammal has a limited home range and can occur in high densities in areas with appropriate food and shelter (i.e., cattail marsh). Muskrats can be used to assess the effects of emissions on local vegetation and surface water resources.
Terrestrial Mammals	Small Mammals	Northern short-tailed shrew	The northern short-tailed shrew may or may not be present at the OPG retained lands. It has been selected as a representative species for small mammals. The northern short-tailed shrew is omnivorous and eats almost their own weight daily. Their diet includes ground-dwelling species (e.g., earthworms) and plant matter. They are common in areas with

Class	VEC	Indicator Species	Rationale
			abundant vegetative cover and can be found in a variety of habitats. They are an important food source for birds of prey, foxes and coyotes. In the context of physical impacts, affects are not commonly assessed. This species can be used to assess the effects of airborne and waterborne emissions that may, in turn, influence forage opportunities.
	Bats	Little Brown Myotis (Little Brown Bat)	Bats are present on-site and are part of the Ontario SAR list.
	Herbivores	White-tailed Deer	Sustainable population of white-tailed deer, that overwinters in the coniferous forest cover and grazes in the fields and woodlands from spring to fall, are present on the Bruce nuclear site. Evidence that the deer population has influenced the development of forested communities at the Bruce nuclear site through selective browsing. The white-tailed deer can be used to assess the effects of emissions that may, in turn, influence forage opportunities, the potential effects of road-related wildlife mortality within the Bruce nuclear site and noise disturbance associated with traffic, construction equipment, and increased human activity.
	Carnivores	Red Fox	The red fox was observed on the WWMF during the most recent wildlife surveys. An active fox den was also observed on the site. It has been chosen as a representative species for carnivorous mammals.

Class	VEC	Indicator Species	Rationale
Species of Ecological Significance (e.g., SAR)	Barn Swallow	Red-Eyed Vireo American Robin	Species of ecological significance which either breed or permanently reside at the OPG retained lands. These species are either listed under the provincial Endangered Species Act, the federal Species at Risk Act, or are considered provincially rare. Indicator species for the SAR have been chosen from the indicators listed above to represent the SAR in the assessment. For non-radiological contaminants, the assessment is not species-specific for terrestrial plants and invertebrates (including insects). For the snapping turtle, individual contaminants are examined for herpetofauna, so there is no difference between species of turtle. For radiological contaminants, the benchmarks are not specified for SAR/non-SAR, and exposures are conservative, so the SAR and the indicator species are conservatively assumed to receive similar doses. Therefore the indicator species are considered appropriate for this assessment.
	Eastern Meadowlark		
	Eastern Wood Pewee		
	Golden-winged Warbler		
	Olive-sided flycatcher		
	Wood Thrush		
	Rusty Blackbird		
	Little Brown Myotis	Little Brown Myotis (Little Brown Bat)	
	Northern Myotis		
	Eastern Small-footed Myotis		
	Monarch Butterfly	Bees	
	Butternut	Eastern White Cedar	
	Sharp Fruited Rush	Grass	
	Snapping Turtle	Painted Turtle	
	Deepwater Sculpin	Deepwater Sculpin	

Table 4-2: Summary of Representative Indicator Species

Class	Indicator Species
Aquatic Vegetation	Cattail
Aquatic Invertebrates	Digger Crayfish
	Benthic Invertebrates
Fish	Northern Redbelly Dace
	Spottail Shiner
	Smallmouth Bass
	Lake Whitefish
	Deepwater Sculpin
Terrestrial Vegetation	Grass
	Eastern White Cedar
Terrestrial Invertebrates	Earthworm
	Bee
Herpetofauna	Northern Leopard Frog
	Spring Peeper
	Painted Turtle
	Northern Water Snake
Birds	Wild Turkey
	Red-Eyed Vireo
	American Robin
	Mallard
	Bald Eagle
Aquatic Mammals	Muskrat
Terrestrial Mammals	Northern Short-tailed Shrew
	Little Brown Myotis (Little Brown Bat)
	White-Tailed Deer
	Red Fox

4.1.1.2 Receptor Characterization

Receptor profiles in Appendix C describe the habitat and the feeding habits of the selected species. The indicator species were assigned to assessment locations on the site based on habitat features at each location and where the receptor is likely to be found. Receptor locations for assessment purposes are discussed in Section 4.1.2.

For mammals, birds, and fish, dietary assumptions were made based on the described feeding habits. Diets were simplified to represent the main food chain pathways without attempting to capture their full taxonomic complexity.

Species-specific exposure parameters, including bioaccumulation factors (for radionuclides), food and water ingestion rates, transfer factors and body weights, are described in Section 4.3.3.

4.1.1.3 Assessment and Measurement Endpoints

Assessment Endpoints

Assessment endpoints are explicit expressions of the environmental value that is to be protected [79]. The assessment endpoint for receptors in this EcoRA is either individual, population, or community success. The assessment endpoint for each indicator species is given in Table 4-3.

Table 4-3: Assessment Endpoints for Indicator Species

VEC/ Indicator Species	Assessment Endpoint		
	Individual success	Population success	Community success
Cattail		X	
Aquatic Vegetation			X
Grass	X*	X	
Eastern White Cedar	X*	X	
Digger Crayfish		X	
Benthic Invertebrates			X
Earthworm		X	
Northern Redbelly Dace		X	
Spottail Shiner		X	
Smallmouth Bass		X	
Lake whitefish		X	
Deepwater Sculpin	X		
Bee	X*	X	
Northern Leopard Frog		X	
Spring Peeper		X	
Painted turtle	X*	X	
Northern Water Snake		X	

VEC/ Indicator Species	Assessment Endpoint		
	Individual success	Population success	Community success
Wild Turkey		X	
Red-Eyed Vireo	X*	X	
American Robin	X*	X	
Mallard		X	
Bald Eagle	X		
Muskrat		X	
Little Brown Bat	X		
Northern short-tailed shrew		X	
White-Tailed Deer		X	
Red Fox		X	
Species at Risk	X		

*Surrogate SARs

The environmental protection goal for this ERA is to maintain population abundance for the majority of individual species, or abundance and diversity where a receptor community is considered, and thereby maintain biodiversity and ecosystem function. For SARs, the goal is for success of the individual. The purpose of the ecological risk assessment is to evaluate whether this is likely to be achieved.

Success of a receptor or receptor category is linked to indicators such as mortality, reproductive impairment, and growth impairment. Success of a receptor is defined on various levels, i.e., individual, population, or community success. Success of an individual receptor is only applicable for SAR, and considers the effects of a contaminant on each individual member of a species as effects on a few individuals are not acceptable. For this ERA, a population is defined as "an assemblage of organisms of a single species that inhabit an area sufficiently small that they are able to interbreed freely" [2]. Success of a population considers the effects of a contaminant on the population of a species as a whole; effects on individuals are not considered unless the species as a whole is put at risk. A community is defined as "an assemblage of organism of multiple species that exist and interact with one another in a particular area" [2]. Success of a community defines the indicator at a level higher than the species level; benchmarks are intended to be protective of the community as a whole rather than of each species. However, in practice, protection at the community level is based on toxicological data for sensitive members of the community.

Measurement Endpoints

Measurement endpoints are conceptually related to assessment endpoints but are quantifiable using standard toxicological methods such as laboratory exposures. They are typically utilized to evaluate whether environmental protection goals are likely to be achieved. These are endpoints such as reproduction, growth and survival that are logically related to maintenance of population abundance, but are more easily inferred from COPC concentration and dose. For wildlife, measurement endpoints are usually defined as some low-effect threshold concentration in a sensitive species, and are given on a species-specific basis for the indicator species in the assessment. For plants and invertebrates, benchmarks are not commonly established based on a sensitive species due to the diversity of plant and invertebrate species that may be present, soil types, chemical forms, and test procedures used in the generation of toxicological data. Instead, a threshold effect concentration that does not result in an effect greater than 25% on representative species is considered protective of plant and invertebrate populations. In this EcoRA, possible effects of COPCs on survival, reproduction, or growth were inferred or predicted by comparison of estimated doses to benchmark doses that have been associated with such effects in the literature.

Considering that SARs may be present on-site or may pass through the site, the No Observed Adverse Effect Level (NOAEL) derived from laboratory studies were selected as the measurement endpoints. The NOAELs are based on studies that assess survival, growth and reproductive effect. For non-Species at Risk (non-SAR) mammals and birds, the Lowest Observed Adverse Effect Level (LOAEL) derived from laboratory studies were selected as the measurement endpoints. The LOAEL is the lowest concentration at which a relevant adverse effect (i.e., diminished growth or fewer offspring) was demonstrated in a study using appropriate exposure conditions.

In summary, the assessment and measurement endpoints are as follows:

- Survival and growth of plants – threshold effects concentration;
- Survival and growth of soil invertebrates – threshold effects concentration;
- Survival, growth and reproduction of mammals – LOAEL (to assess non-SAR only) and NOAEL (to assess SAR only); and,
- Survival, growth and reproduction of birds – LOAEL (to assess non-SAR only) and NOAEL (to assess SAR only).

The benchmark values used are presented in Section 4.3.4.

4.1.2 Ecological Conceptual Model and Exposure Pathways

4.1.2.1 Conceptual Model

The conceptual model illustrates how receptors are exposed to COPCs. It identifies the source of contaminants, receptor locations, and the exposure pathways to be considered in the assessment for each receptor. Exposure pathways represent the various routes by which COPCs enter the body of the receptor, or (for radionuclides) how they may exert effects from outside the body.

The potential exposure pathways considered in this assessment included exposure to air, water, soil, and sediment, and various dietary components for different species and receptor categories. Detailed potential exposure pathways for aquatic and terrestrial receptors for both radiological and non-radiological contaminants are given in Figure 4-1 and Figure 4-2.

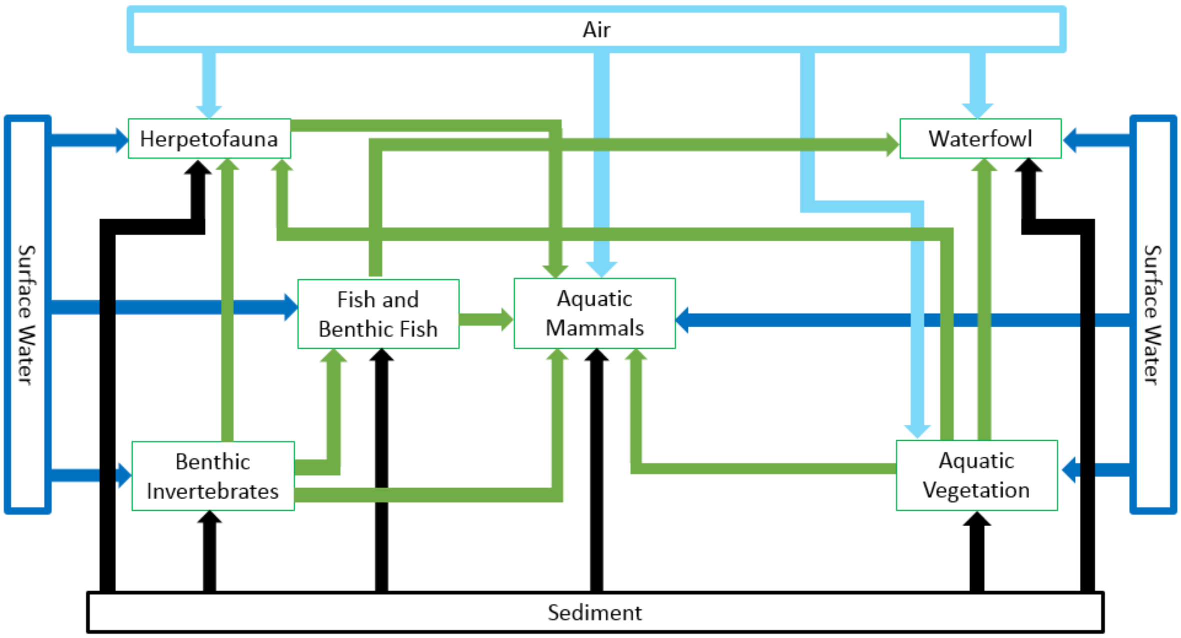

Figure 4-1: Potential Exposure Pathways for General Aquatic Receptors

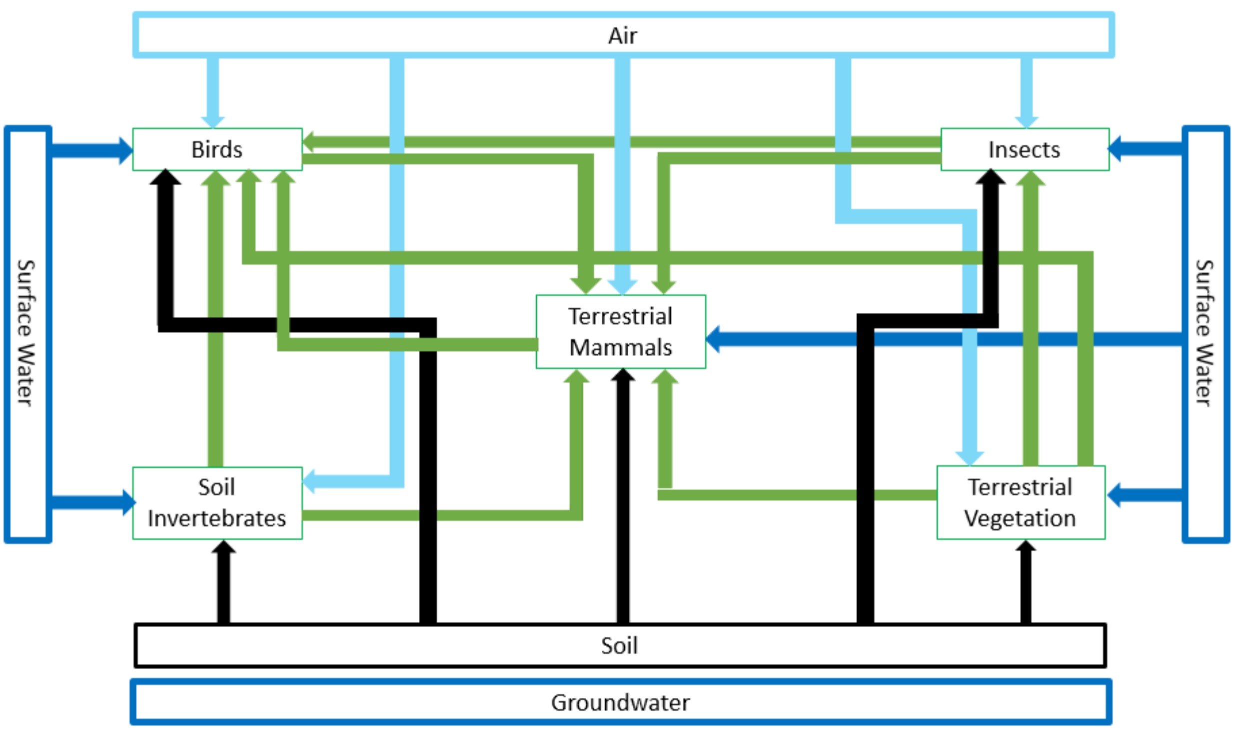

Figure 4-2: Potential Exposure Pathways for General Terrestrial Receptors

The pathways presented in Figure 4-1 and Figure 4-2 are all potential pathways of exposure for the aquatic and terrestrial receptors. Exposure pathways considered in the assessment differ between the radiological and non-radiological COPCs, as discussed in the sections below.

Radiological Contaminants

For radiological contaminants, exposures from air, surface water, soil, sediment, and vegetation are relevant. Exposures from each medium are considered for each receptor; no pathway is considered to result in minimal exposure and therefore no pathway is excluded from the assessment so long as there is a means of exposure.

For radiological contaminants, the conceptual model for ecological receptors should also take into account external exposure in addition to exposure to environmental contamination through different pathways.

Non-Radiological Contaminants

The potential exposure pathways given in Figure 4-1 and Figure 4-2 were assessed for non-radiological COPCs as part of the screening assessment in Section 4.3.2. The result was that exposure to COPCs from air and groundwater were determined to not be a concern. Media with COPCs, as determined by the screening assessment in Section 4.3.2, are surface water, soil, and sediment. These media have been considered with their various routes of exposure in Figure 4-3 to form the site-specific conceptual model for non-radiological COPCs and to determine the relevant exposure pathways for ecological receptors to non-radiological COPCs.

Exposure pathways have been screened in Figure 4-3 as complete, minimal, incomplete, and not applicable. Complete pathways have been included in the assessment. Pathways by which a receptor may receive minimal exposure to a COPC have not been included in the assessment as they are not considered to be significant in comparison to the exposure from the complete pathways. Pathways that are "not applicable" are pathways by which it is not considered possible or probable for a receptor to be exposed by a COPC, either due to lack of exposure to the medium or the nature of the receptor. Alternatively, "not applicable" may indicate that the media is not applicable, as exposure is assessed through other media.

Pathways with minimal exposure are identified as such in Figure 4-3. For example:

- Dermal exposure to ecological receptors is generally prevented by fur or feathers, and has therefore not been included for terrestrial receptors.
- Exposure through the ingestion of surface water by terrestrial receptors results in minimal exposure and has therefore not been included.
- Inhalation exposure was excluded from the table as exposures from the inhalation route are typically much less than from the ingestion pathway and as there were no COPCs identified in air [2].
- Sediment ingestion by fish is incidental; exposure to sediment contaminants through ingestion of prey (i.e., benthic invertebrates) is considered to be a more significant and more quantifiable pathway.

Source	Release and Transport	Exposure Route	WWMF and Bruce nuclear site: Terrestrial Plants	Terrestrial Insects	Terrestrial Soil Invertebrates	Terrestrial Mammals and Birds	Aquatic Mammals and Birds	Amphibians	Reptiles	Aquatic Plants	Aquatic Invertebrates	Fish	Lake Huron: Fish
COPCs in Soil		Soil Ingestion	N/A	Yes	Yes	Yes	Min	Yes	Yes	N/A	N/A	N/A	N/A
COPCs in Soil		Soil Inhalation	N/A	Min	Min	Min	Min	Min	Min	N/A	N/A	N/A	N/A
COPCs in Soil		Root Uptake/ Dermal Contact	Yes	Min	Yes	Min	Min	Min	Yes	N/A	N/A	N/A	N/A
COPCs in Soil	Particulate Matter	Inhalation	Min	Min	Min	Min	Min	Min	Min	N/A	N/A	N/A	N/A
COPCs in Soil	Uptake by plants/ intake by prey	Ingestion of Plants and Prey	N/A	Yes	Min	Yes	Min	Yes	Yes	N/A	Min	N/A	N/A
COPCs in Soil → COPCs in Surface Water	Leaching												
COPCs in Surface Water		Water Ingestion	N/A	N/A	N/A	Min	Yes	Yes	Yes	N/A	Yes	Yes	Yes
COPCs in Surface Water		Immersion / Dermal Contact	N/A	N/A	N/A	Min	Yes	Yes	Yes	Yes	Yes	Yes	Yes
COPCs in Surface Water	Uptake by plants/ intake by prey	Ingestion of Plants and Prey	N/A	N/A	N/A	Min	Yes	Yes	Yes	N/A	N/A	Yes	Yes
COPCs in Surface Water → COPCs in Sediment	Deposition												
COPCs in Sediment		Sediment Ingestion	N/A	N/A	N/A	N/A	Yes	Min	Yes	N/A	N/A	N/A	N/A
COPCs in Sediment		Immersion/ Dermal Contact	N/A	N/A	N/A	N/A	Min	Yes	Yes	N/A	Yes	Min	Yes
COPCs in Sediment	Uptake by plants/ intake by prey	Ingestion of Plants and Prey	N/A	N/A	N/A	N/A	Yes	Yes	Yes	N/A	Yes	Min	N/A

Yes Exposure pathway complete
Min Exposure considered minimal and will not be assessed quantitatively.
N/A Not applicable

Figure 4-3: Conceptual Model for COPCs at the WWMF and Vicinity

4.1.2.2 Exposure Pathways for Non-Radiological COPCs

The exposure pathways are the routes by which COPCs gain access to a receptor.

The exposure pathways examined in the conceptual site model for non-radiological COPCs are presented in Table 4-4. These pathways were considered for the non-radiological assessment.

Pathways shown in Figure 4-3 as minimal exposure ("Min") were excluded from the table due to being relatively insignificant.

Most of the habitats considered in this assessment are within the bounds of the Bruce nuclear site, in areas on or immediately adjacent to the WWMF to ensure that the most exposed species are evaluated ("On-site" locations). A single exception is fish, which was considered in Lake Huron as well as in the ditches in the vicinity of WWMF. This was included to ensure that deep-water fish species are considered.

Table 4-4: Exposure Pathways for Non-radiological COPCs

Class/Community	Location	Exposure Pathways	Environmental Medium	Receptor
Aquatic Vegetation	On-Site	Immersion	Surface Water	Cattail population
Benthic Invertebrates	On-Site	Immersion	Surface Water	Benthic invertebrate community
			Sediment	Benthic invertebrate community
Fish	On-Site / Lake Huron	Immersion	Surface Water	Northern Redbelly Dace, Spottail Shiner, Smallmouth Bass, Lake Whitefish, Deepwater Sculpin[A] populations
Terrestrial Vegetation	On-Site	Root Uptake/ Immersion	Soil	Grass and Eastern White Cedar populations
Terrestrial Invertebrates	On-Site	Immersion/ Direct Contact	Soil	Earthworm and Bee populations.
Amphibians / Reptiles	On-Site	Immersion	Surface Water	Leopard Frog, Spring Peeper, Northern Water Snake, and Painted Turtle populations
	On-Site	Direct Contact	Soil	
Aquatic Birds	On-Site	Ingestion	Surface Water	Mallard and Bald Eagle populations
			Sediment	
			Food Item (Cattail Measurements, Uptake into fish and invertebrates)	
Terrestrial Birds	On-Site	Ingestion	Soil	Wild turkey, American Robin, Red-eyed Vireo, And Bald Eagle populations
			Food Items (Uptake into vegetation, earthworms and/or prey items)	
Aquatic Mammals	On-Site	Ingestion	Surface Water	Muskrat population
			Sediment	
			Food Items (Cattail Measurements)	
Terrestrial Mammals	On-Site	Ingestion	Soil	Northern Short-tailed Shrew, Little Brown Myotis (bat), White-Tailed Deer and Fox populations
			Food Items (Uptake into vegetation, earthworms and/or prey items)	

[A]Most sensitive species assessed, based on available toxicological information.

4.2 Assessment of Radiological Impact

In this EcoRA, the impact of radiological contaminants is assessed in a manner that considers the impact of multiple radionuclides and pathways on non-human biota. This corresponds to Tier 2 assessment (PQRA). On this basis, an HQ is determined and the risk is quantitatively assessed.

4.2.1 Exposure Point Concentrations and Doses

In this assessment, the concentrations of radionuclides in air were estimated based on air dispersion modelling using a computer code, IMPACT, with details presented in Appendix D. Radionuclide concentrations in soil and vegetation were obtained from baseline monitoring field studies performed on the potential WWMF expansion areas. Sampling was performed in accordance with CSA N288.4-10 [1]. The general sampling locations for radiological monitoring are shown in Figure 4-4.

Concentrations of radionuclides in water were obtained from a variety of sources. Tritium concentrations were obtained from the WWMF One-Year Supplementary Study [80][21]. Tritium sampling was performed at five locations, including the Upstream ditch, the LLSB discharge, and downstream of the discharge.

Concentrations of C-14 in surface water were obtained from analytical reports for sampling performed in the SRD in 2013 and 2014 ([81], [82], [83], [84]). Sampling was performed at three locations as shown in Figure 4-4:

1. SRD-2 (Location C): At the east end of the site, north of the Western Used Fuel Dry Storage Facility;
2. GS-1 (Location D): At the discharge following the last settling pond of the Grassed Swale; and,
3. SRD-3 (Location E): At the corner of Gantry Crane Road and the railway tracks, at the base of the stairs leading down to the ditch.

Sediment sampling was also performed in the SRD at SRD-2, GS-1 and SRD-3 (locations C-E) in 2013 and 2014 and analyzed for C-14 and beta/gamma emitters [81], [85].

This radiological data set is used to form the current conditions of the ecological environment. A summary of this data set is available in Appendix G. A summary of the radiological contaminants, their maximum concentrations which were used for calculation, the media in which they were measured, and their sampling locations can be found below.

[21] Tritium concentrations in surface water could be affected by groundwater which could potentially discharge to surface water. More information about groundwater quality can be found in Appendix B.

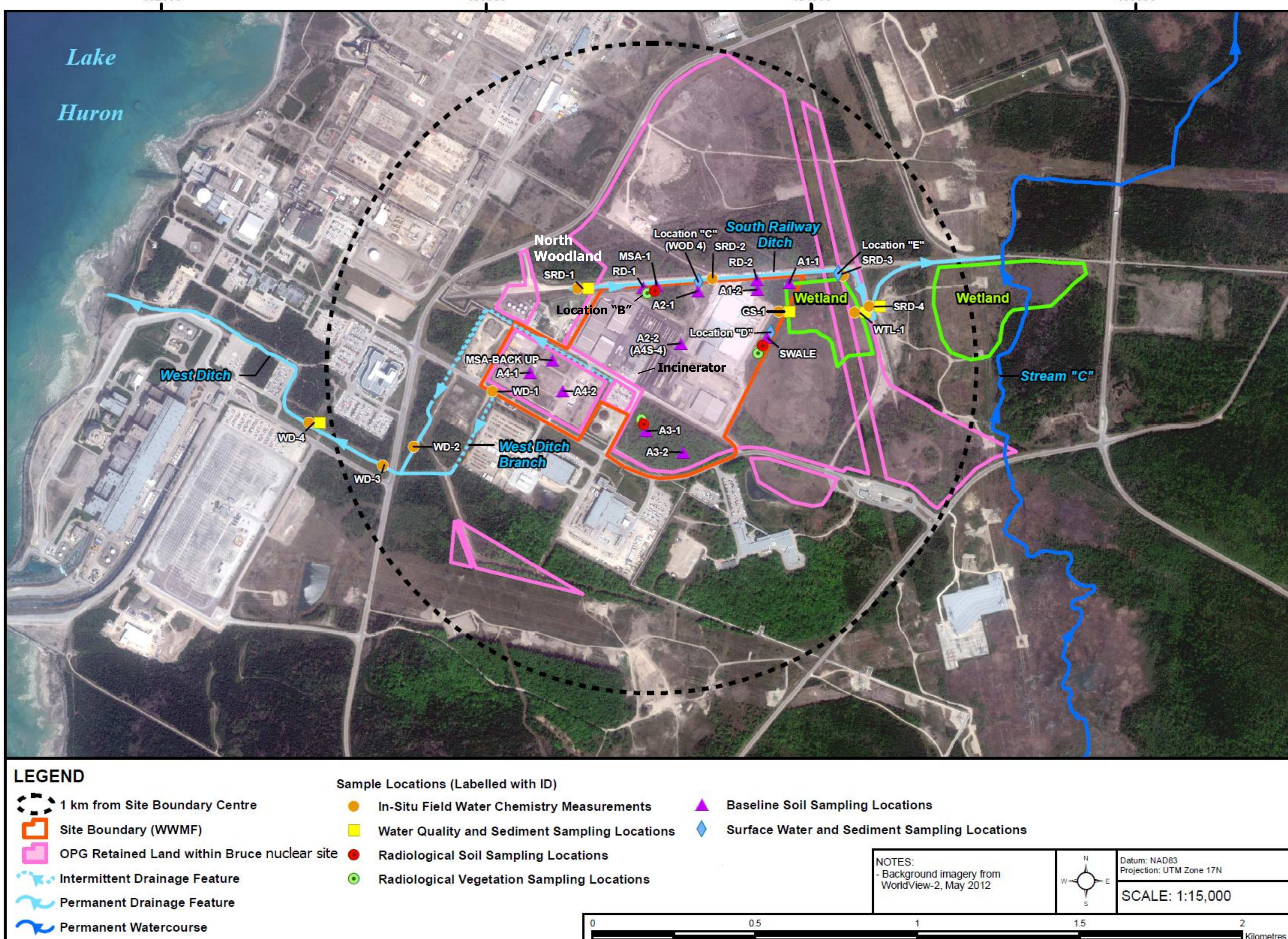

Figure 4-4: Environmental Sampling Locations

In this assessment, tritium (HTO), C-14, Cs-134, Cs-137, Co-60 and I-131 were selected for the dose calculations. These radionuclides were selected because of their prevalence in the environment and their relevance to the emission of the WWMF as discussed in Section 2.2.9 and other nuclear facilities at the Bruce nuclear site, specifically BNGS-A and BNGS-B which are the major contributors to radiological emissions.

4.2.1.1 Concentrations in Air

Concentrations of radionuclides in air were modelled using the computer code IMPACT. See Appendix D.5 for the air monitoring data and determination of the data used in the assessment.

The air concentrations of the selected radionuclides were determined at four locations (100 m from the incinerator in each compass direction[22]) with respect to the incinerator at the WWMF. The maximum value for each radionuclide was used for the assessment. See Table 4-5 for the concentrations determined by the model.

Table 4-5: Radionuclide Concentrations in Air

Radionuclide	**C-14**	**Cs-134**	**Cs-137**	**Co-60**	**Tritium**	**I-131**
Concentration (Bq/m^3)	0.043	1.30E-06	1.30E-06	1.30E-06	78.00	1.30E-06

4.2.1.2 Soil and Vegetation Concentrations

Monitoring of soil was performed as part of the baseline monitoring program; soil monitoring locations are illustrated in Figure 4-4. Radionuclide concentrations in soil were measured as Bq/kg dry weight (dw). Table 4-6 below gives the maximum concentration of each radionuclide in both surface and subsurface soil, as well as the conversion to Bq/kg wet weight (ww).

Monitoring of radionuclides in vegetation was performed as part of the baseline monitoring program; vegetation (cedar and foodstuff) was measured at the sampling points illustrated in Figure 4-4. Radionuclide concentrations were measured as Bq/kg ww. Table 4-7 below gives the maximum concentrations of each radionuclide measured in both cedar and foodstuff.

[22] The nearest distance from the center of the WWMF to the existing WWMF fence line is approximately 100 m. It has been conservatively assumed that indicator species reside around the WWMF fence line. Therefore, 100 m was selected to represent the distance from the emission source to the location of the indicator species. It should be noted that the locations of different species will vary. The 100 m distance selected is conservative and is considered appropriate for the purpose of the ERA.

Table 4-6: Maximum Radionuclide Concentrations in Soil

Radionuclide	Subsurface Soil			Surface Soil				
	Conc. (Bq/kg ww)	Sampling Season	Sampling Point	Conc. (Bq/kg dw)	Sample Mass (kg dw)	Conc. (Bq/m²)^	Sampling Season	Sampling Point
Tritium (HTO)‡	512	Spring	South of incinerator	729‡	0.0076‡	245.04	Spring	South of incinerator
C-14†	19.7	Spring	South of incinerator	28.55	0.0006	0.79	Spring	South of incinerator
Co-60	0.7*	Spring	East of incinerator	1.8	0.588	47.04	Summer	North Woodland
Cs-134	0.65*	Spring	South of incinerator	3.0	0.498	66.40	Spring	East of incinerator
Cs-137	29.2	Spring	South of incinerator	51.6	0.25	573.33	Spring	South of incinerator
I-131	32.8*	Spring	East of incinerator	66.5*	0.2	591.11	Spring	South of incinerator

ww – wet weight
dw – dry weight
‡Surface soil samples were analysed wet for tritium. All other soil samples were analysed dry.
*These radionuclides were not detected. Concentrations are ½ Method Detection Limit (MDL).
^assume sample area 0.0225 m^2 (15 cm x 15 cm)
†Concentrations were measured as Bq/kg-C. For the purpose of unit conversion from Bq/kg-C to Bq/kg soil, the soil carbon content is assumed to be 5% and soil water content is assumed to be 10%.

Table 4-7: Maximum Radionuclide Concentrations in Vegetation

Radionuclide	Foodstuff			Cedar		
	Concentration (Bq/kg ww)	Sampling Season	Sampling Point	Concentration (Bq/kg ww)	Sampling Season	Sampling Point
Tritium (HTO)	921	Fall	North woodland	1240	Winter	North woodland
C-14+	41.65	Fall	South of incinerator	43.9	Winter	South of incinerator
Co-60	5.6	Summer	North woodland	1.25*	Winter	South of incinerator
Cs-134	1.45*	Summer	North woodland	1.1*	Winter	South of incinerator
Cs-137	1.65*	Summer	South of incinerator	1.6*	Summer	South of incinerator
I-131	262.5*	Spring	South of incinerator	3700*	Winter	South of incinerator

*These radionuclides were not detected. Concentrations are ½ MDL.
†Carbon content of fresh plants is assumed to be 5% for the purpose of unit conversion from Bq/kg-C to Bq/kg fresh plant.

4.2.1.3 Concentrations in Surface Water

The maximum concentration of each radionuclide in surface water was obtained from on-site monitoring programs. Some concentrations were measured in Bq/kg; these were converted to Bq/L assuming a water density of 1.0 kg/L; tritium was directly measured in Bq/L. Sampling locations are outlined in Section 4.2.1. The concentrations are given in Table 4-8.

Table 4-8: Maximum Radionuclide Concentrations in Water

Radionuclide	Concentration (Bq/L)	Sampling Location	Sampling Season	Reference
C-14	1.02	SRD-3	Summer	[84]
Tritium (HTO)	3320	B**	Summer	[80]
Co-60	0.5*	All	Fall	[82]
Cs-134	0.5*	All	Fall	[82]
Cs-137	0.5*	All	Fall	[82]
I-131	0.5*	All	All	[82]

*These radionuclides were not detected. Concentrations are ½ MDL.
**Location B is between SRD-1 and SRD-2.

4.2.1.4 Concentrations in Sediment

The maximum concentration of each radionuclide in sediment was obtained from on-site monitoring programs. Radionuclide concentrations in sediment were measured as Bq/kg dw. Sampling locations are outlined in Section 4.2.1. The concentrations are given in Table 4-9.

Table 4-9: Maximum Radionuclide Concentrations in Sediment

Radionuclide	Moisture content (%)	Concentration (Bq/kg dw)	Concentration (Bq/kg ww)	Sampling Location	Sampling Season	Reference
C-14^{+}	80	24	5.6	SRD-3	Spring	[85]
Co-60	80	0.1*	0.4	All	Spring	[85]
Cs-134	80	0.5*	0.5	All	Summer	[81]
Cs-137	80	6.6	1.7	GS-1	Spring	[85]
I-131	80	1550*	310.4	SRD-3	Spring	[85]

*These radionuclides were not detected. Concentrations are ½ MDL.
$^{+}$Carbon content of sediment is assumed to be 5% for the purpose of unit conversion from Bq/kg-C to Bq/kg sediment.

4.2.1.5 Radiological Doses to Ecological Receptors

Doses to receptor species were calculated using the computer code AICER (Version 1.0.0.0) [86]. AICER is consistent with CSA N288.6-12 [2] regarding ecological risk assessment for radiological exposures to non-human biota. Doses to the indicator species were calculated using the estimated concentration data, presented in Sections 4.2.1.2- 4.2.1.4 above, as inputs to the code. The results are presented both as a total dose and by radionuclide in Table 4-10.

It should be noted that indicator species could receive radiation doses from direct external exposure to gamma radiation from the waste storage facilities at the WWMF. This has been taken into account in the calculation of dose to non-human biota by conservatively assuming that all indicator species receive a gamma dose of 0.155 μGy/h, which is the maximum dose rate measured at the boundary of the WWMF for the period of
2009-2013.

The theoretical basis and the default AICER parameter values used for dose calculation are presented in Appendix D.

Table 4-10: Estimated Radiological Doses to Ecological Receptors

Indicator Species	Dose by Radionuclide (µGy/h)						Environmental Pathway Dose (µGy/h)	Direct External Exposure Dose (µGy/h)	Total Dose (µGy/h)
	Tritium	C-14	Co-60	I-131	Cs-134	Cs-137			
Cattail	0.016	0.171	0.035	0.030	0.013	0.015	0.28	0.155	0.43
Grass	0.006	0.001	0.001	0.031	0.001	0.004	0.044	0.155	0.20
Cedar	0.008	0.001	0.001	0.911	0.001	0.003	0.925	0.155	1.08
Digger Crayfish	0.016	0.150	0.012	0.030	0.010	0.009	0.229	0.155	0.38
Benthic Invertebrate	0.016	0.150	0.012	0.030	0.010	0.009	0.229	0.155	0.38
Northern Redbelly Dace	0.016	0.165	0.006	0.030	0.358	0.321	0.896	0.155	1.05
Spottail Shiner	0.016	0.165	0.006	0.030	0.358	0.321	0.896	0.155	1.05
Lake Whitefish	0.016	0.165	0.006	0.003	0.358	0.321	0.870	0.155	1.02
Smallmouth Bass	0.016	0.165	0.006	0.001	0.358	0.321	0.867	0.155	1.02
Deepwater Sculpin	0.016	0.165	0.006	0.015	0.358	0.321	0.882	0.155	1.04
Earthworm	0.077	0.001	0.001	0.008	0.001	0.011	0.098	0.155	0.25
Bee	0.030	0.006	0.000	0.228	0.000	0.000	0.264	0.155	0.42
Northern Leopard Frog	0.022	0.211	0.005	0.032	0.104	0.124	0.497	0.155	0.65
Spring Peeper	0.022	0.211	0.005	0.016	0.104	0.125	0.482	0.155	0.64
Painted Turtle	0.022	0.211	0.005	0.032	0.104	0.124	0.497	0.155	0.65
Northern Water Snake	0.022	0.211	0.005	0.032	0.104	0.124	0.497	0.155	0.65
Red-Eyed Vireo	0.046	0.001	0.000	0.000	0.000	0.000	0.047	0.155	0.20
American Robin	0.046	0.001	0.000	0.001	0.000	0.001	0.050	0.155	0.21
Mallard	0.014	0.311	0.008	0.000	0.010	0.008	0.351	0.155	0.51
Wild turkey	0.017	0.002	0.001	0.003	0.001	0.002	0.025	0.155	0.18
Bald Eagle	0.013	0.326	0.003	0.000	0.494	0.420	1.257	0.155	1.41
Muskrat	0.014	0.340	0.005	0.016	0.738	0.738	1.849	0.155	2.00
Little Brown Bat	0.020	0.012	0.000	0.001	0.000	0.000	0.032	0.155	0.19
Northern short-tailed shrew	0.040	0.001	0.001	0.004	0.001	0.006	0.052	0.155	0.21
White-Tailed Deer	0.009	0.002	0.001	0.175	0.002	0.002	0.190	0.155	0.35
Red Fox	0.017	0.003	0.000	0.001	0.001	0.001	0.023	0.155	0.18

4.2.2 Radiation Benchmarks

The following dose benchmark values, as recommended in CSA N288.6-12 [2], will be used in this assessment:

- 100 μGy/h for terrestrial biota, and;
- 400 μGy/h for aquatic biota.

4.2.3 Risk Characterization

Risk will be quantified for each category based on the calculation of an HQ.

If the HQ for each radiological COPC is less than one, then no adverse effects are likely as concentrations are below levels that are known to cause adverse effects. If the HQ exceeds one, it may be inferred that adverse effects to individuals are possible. Inferences about potential effects can be made given a certain magnitude and type of effect associated with the assessment benchmark or endpoint. An HQ > 1 indicates that there is the potential for adverse effects and further assessment is required.

In general terms, an increase in exposure is associated with an increase in risk. As the magnitude of the HQ increases so does the potential for environmental effects, the likelihood of the effect depending on the magnitude of exposure and the endpoint used to assess effects.

The radiological risk to non-human biota will be quantified based on the calculation of a HQ for each indicator species with the following equation:

$$HQ = \frac{Calculated\ radiation\ dose}{Radiological\ criteria}$$

For radiological risk, the HQ is calculated based on the total dose received by each receptor from all radionuclides through all pathways. The calculated radiation dose received by each receptor is given in Table 4-10 and the radiological criteria are listed in Section 4.2.2 as dose benchmark values.

The HQ for each indicator species is given in Table 4-11.

Table 4-11: Radiological Risk Characterization

Class/Community	Indicator Species	Total Dose (µGy/h)	Criterion (µGy/h)	HQ
Aquatic Vegetation	Cattail	0.43	400	0.0011
Terrestrial Vegetation	Grass	0.20	100	0.0020
	Cedar	1.08	100	0.0108
Aquatic Invertebrate	Burrowing Crayfish	0.38	400	0.0010
	Benthic Invertebrate	0.38	400	0.0010
Fish	Northern Redbelly Dace	1.05	400	0.0026
	Spottail Shiner	1.05	400	0.0026
	Lake Whitefish	1.02	400	0.0026
	Smallmouth Bass	1.02	400	0.0026
	Deepwater Sculpin	1.04	400	0.0026
Terrestrial Soil Invertebrate	Earthworm	0.25	100	0.0025
Insects	Bee	0.42	100	0.0042
Herpetofauna	Northern Leopard Frog	0.65	100	0.0065
	Spring Peeper	0.64	100	0.0064
	Painted Turtle	0.65	100	0.0065
	Northern Water Snake	0.65	100	0.0065
Birds	Red-Eyed Vireo	0.20	100	0.0020
	American Robin	0.21	100	0.0021
	Mallard	0.51	100	0.0051
	Wild turkey	0.18	100	0.0018
	Bald Eagle	1.41	100	0.0141
Aquatic Mammals	Muskrat	2.00	100	0.0200
Terrestrial Mammals	Little Brown Bat	0.19	100	0.0019
	Northern short-tailed shrew	0.21	100	0.0021
	White-Tailed Deer	0.35	100	0.0035
	Red Fox	0.18	100	0.0018

The radiological HQ for each indicator species is less than 1; therefore the total dose received by each indicator species is below the benchmark values given in CSA N288.6-12 [2]. These doses are based on the maximum radionuclide concentrations at the WWMF for each medium and therefore represent the maximum dose the indicator species could receive from the existing environment at or near the WWMF; analysis of doses at individual monitoring locations is therefore not required. Therefore, there are not considered to be adverse effects from the radiological COPCs and no further analysis is required.

4.3 Assessment of Non-Radiological Impact

4.3.1 Screening Criteria

CSA N288.6-12, Clause 7.2.5.3.1, indicates that "For non-radiological COPCs, the most restrictive applicable federal or provincial guidelines for environmental quality should be used as screening criteria, if such guidelines are available, because their values are intended to be protective of all or most organisms in the media to which they apply" [2].

At the WWMF, SARs are present, which excludes the use of the Table 3 provincial values developed by the Ministry of the Environment [87] to be protective of ecological receptors. These are risk-based values and not all considered appropriate for SARs. The Table 1 values (which represent background) are to be employed based on the presence of SARs.

As such, the following sources will be used to determine the non-radiological criteria:

- CCME Canadian Environmental Quality Guidelines [88];
- Ontario Provincial Water Quality Objectives (PWQO) [89];
- Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act [87]; and,
- CCME Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil [90].

In the absence of environmental quality guidelines, concentrations considered representative of the background will be used in the screening process. Sources for these levels include:

- Ontario Ministry of the Environment (MOE) Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario [65];
- Ontario Ministry of the Environment and Energy Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow [91]; and,
- Chemical-Specific information provided by reputable sources (e.g., Health Canada, ATSDR and the WHO).

4.3.2 Screening

Screening of non-radiological contaminants to determine COPCs was performed in accordance with CSA N288.6-12 [2], based on comparison to guideline concentrations. Environmental concentrations found in the WWMF that do not exceed the guideline concentration listed in Section 4.3.1 above are not considered to be of concern and do not require further assessment.

The primary environmental data for soil, sediment, surface water, and groundwater used as input to the screening assessment was obtained from baseline monitoring field studies performed in the potential WWMF expansion area. Sampling was performed in accordance with CSA N288.4-10 [1]. The baseline field studies involved sampling and analysis of groundwater, soil, surface water, and sediment from locations within and around the WWMF. The sampling targeted areas that had not been previously assessed or where historic data required confirmation. This data set is used to form the "current conditions" of the ecological environment.

The maximum value for the environmental concentrations in each medium was used in the screening assessment. For the baseline sampling data where field duplicate samples were taken, an average concentration was calculated as the representative concentration for that sample location. For the EMP data, samples collected were split into triplicate for analysis. Values for each sample were averaged between the triplicate samples and the resultant maximum value was used for the screening assessment. In any cases where the Reportable Detection Limit (RDL) or MDL was higher than the guideline concentration, the concentration was assumed to exceed the guideline.

A summary of the contaminants which exceed the guideline concentrations and the media in which they were detected can be found in Table 4-23. Further discussion of each medium is provided below.

4.3.2.1 Air

Sampling of environmental concentrations in air was not performed as part of the WWMF Expansion Baseline Monitoring. The most recent Emissions Summary and Dispersion Modelling Report [55] was used as the source of data.

Inhalation exposures to biota are usually minor compared to soil and food ingestion pathways; they can be ignored for most substances, with the exception of substances that do not partition to soil [2]. These substances include gases such as nitrogen oxides (NO_x) and sulphur dioxide (SO_2). For these substances, air concentrations dominate the exposure pathway for terrestrial biota. The main source of these compounds is combustion; at the WWMF, the only significant source of emissions to air is the incinerator [55]. The results of the air dispersion modelling for contaminants of interest to the EcoRA are summarized in Table 3-6.

Significant contaminants emitted from the incinerator include NO_x, hydrogen chloride (HCl), and chromium VI (Cr (VI)). The maximum POI concentrations modelled for these contaminants are well below the MOE POI limits, and are therefore not likely to have potential effects on ecological receptors located on site. In addition, these contaminants were not measured at levels determined to be of significance in soil (see Section 4.3.2.3), and therefore the concentrations of these substances in air have not been significant enough for substantial deposition to soil to occur. Therefore they have been screened out as not being of concern.

Dioxins and furans have been considered further for inhalation by ecological receptors. These contaminants were determined to be negligible in the Emissions Summary and Dispersion Modelling report [55], however they have been considered for direct incinerator stack emissions. Dioxins and furans have been considered due to their high toxicity and because they have exhibited elevated levels in some soils on the WWMF, as discussed in Section 4.3.2.3. Dioxins and furans bind strongly to soils, and are persistent and bioaccumulative in organic tissue [92]. The direct stack emissions for these contaminants have been summarized in Table 4-12, in terms of Toxic Equivalency Quotient (TEQ).

Table 4-12: Incinerator Stack Emission Concentrations [93]

Parameter	Unit	Incinerator Concentration (2009 - 2013)		Limit	Carry Forward to Tier 2?
		Minimum	Maximum		
Dioxins and Furans*	pg TEQ/Rm^3	<1.79	<4.73	80	No

* Rm^3 - Reference m^3, adjusted to 11% oxygen, dry at 25°C and 1 atmosphere

The allowable emission concentration limit for dioxins and furans in the stack gases from the incinerator as per the ECA is a maximum of 80 pg TEQ/Rm^3. The average emissions concentration value measured from the stack in 2013 was <1.80 pg TEQ/Rm^3; the maximum emission concentration measured in the five year dataset was <4.73 pg TEQ/Rm^3, measured in 2009. The level of quantification for the combined dioxin and furan congeners is 32 pg TEQ/Rm^3; concentrations below this level are not reliably quantifiable [93]. The CCME Canada-Wide Standard for dioxins and furans states that the goal for dioxins and furans is virtual elimination; concentrations less than the level of quantification have been obtained for at least the past five years, which indicates that steps toward virtual elimination have been taken [94]. Since these measurements are below the allowable emission concentration given in the ECA and demonstrate steps toward virtual elimination, airborne concentrations of dioxins and furans at the incinerator outlet are not considered to be a concern and therefore inhalation of dioxins and furans has not been considered further.

Therefore no airborne contaminants are of concern to ecological receptors and they are not discussed further in this assessment.

4.3.2.2 Groundwater

Groundwater monitoring at the WWMF was performed as part of the baseline monitoring program. Screening guidelines were obtained from Table 3 of the Federal Contaminated Sites Action Plan (FCSAP) Guidance Document on Federal Interim Groundwater Quality Guideline for Federal Contaminated Sites [95]. The FCSAP guidelines, where available, represent surface water values protective of aquatic receptors. Due to variations in chemistry within a groundwater system and a surface water system, chemicals in groundwater can be naturally present at greater concentrations than found in surface water. As such, where a FCSAP guideline was exceeded, or not available, naturally occurring concentrations identified in groundwater by the MOECC were identified. The screening assessment for all groundwater contaminants that were detected can be found in Table 4-13. The only chemical of interest is orthophosphate. A summary of groundwater contaminants data can be found in Appendix G.

Table 4-13: Groundwater Screening Results

Parameter	Units	Maximum Concentration	FCSAP Table 3 - Freshwater Life	Above Guideline	Comment
Total Dissolved Solids	mg/L	1340	NV	N/A	Used as a check in groundwater sampling, not a chemical requiring evaluation.
Fluoride (F-)	mg/L	2.1	0.12	Yes	Fluoride concentrations within range of background in groundwater (i.e., Ontario background of 2.09 mg/L) [65]. No additional evaluation.
Orthophosphate (P)	mg/L	0.62	NV	NV	Orthophosphate concentrations greater in groundwater than typical (i.e., Ontario background of 0.21 mg/L) [65]. See additional discussion.
Dissolved Sulphate (SO_4)	mg/L	730	100	Yes	Sulphate within range of background in groundwater (i.e., Ontario background of 1070 mg/L) [65]. No additional evaluation.
Nitrite	mg/L	0.027	0.06	No	
Chloride	mg/L	100	120	No	
Antimony	µg/L	1.2	2000	No	
Arsenic	µg/L	11	5	Yes	Arsenic concentrations within range of background in groundwater (i.e., Ontario background of 13 µg/L) [87]. No additional evaluation.
Barium	µg/L	2200	2,900	No	
Boron	µg/L	360	5,000*	No	
Copper	µg/L	1.6	2 to 4	No	
Molybdenum	µg/L	6.2	73	No	
Nickel	µg/L	3.8	76.03 to 150	No	
Sodium	µg/L	58000	NV	NV	Sodium concentrations within range of background in groundwater (i.e., Ontario background of 490,000 µg/L) [87]. No additional evaluation.
Thallium	µg/L	0.069	0.8	No	
Vanadium	µg/L	1.2	NV	NV	Vanadium concentrations within range of

Parameter	Units	Maximum Concentration	FCSAP Table 3 - Freshwater Life	Above Guideline	Comment
					background in groundwater (i.e., Ontario background of 3.9 µg/L) [87]. No additional evaluation.
Zinc	µg/L	21	30	No	
Uranium	µg/L	6.8	15	No	

N/A – Not applicable
NV – No value
*Value not available for freshwater life, value provided is for marine life.

Orthophosphate is one form of phosphate in water, which contains phosphorous. Orthophosphate above levels typical of groundwater was identified in well WSH229, which is not known to discharge to the SRD. Well WSH229 discharges to bedrock and eventually to Lake Huron. Downgradient groundwater concentrations in the bedrock (i.e., well WSH238) were identified as having phosphate concentrations below typical background (i.e., 0.21 mg/L). It is further noted that surface water concentrations in the vicinity of well WSH229 (i.e., SRD-2) show no concerns with respect to phosphorous (i.e., all concentrations are <30 μg/L; 24 μg/L, 2 μg/L, 23 μg/L). As such, there is no indications that phosphorous concentrations associated with well WSH229 are impacting surface water on-site or off-site.

No groundwater contaminants were identified as being of concern to ecological receptors and, as such, groundwater is not discussed further in this assessment.

4.3.2.3 Soil

Sampling of environmental concentrations in soil was performed as part of the WWMF baseline monitoring studies. Locations for baseline sampling for soil can be found in Figure 4-4.

Environmental concentrations in soil were screened against MOE Table 1 Site Condition Standards (SCS) [87] and CCME Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health [88] for industrial land use.

Section 7.2.5.3.1 of CSA N288.6-12 [2] indicates the screening is to be completed using the most restrictive federal or provincial guideline. Environmental concentrations in soil were screened against the CCME Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health [88] for industrial land use. With respect to the provincial guidelines, the Table 1 SCS (which represent background) were employed based on the presence of SARs. Specifically, the risk based standards developed by the MOECC to support the soil standards (i.e., Table 3 SCS) are not all considered appropriate for SARs. However, the MOECC did not develop component values protective of ecological receptors for the PHC guidelines, but adopted the CCME values for screening purposes [65]. As such, the CCME ecological direct soil contact guidelines, which are protective of species at risk, were used in the screening of PHCs.

For a number of substances present in soil, particularly VOCs, the maximum concentration was below the MDL. In these cases, concentrations were assumed to be the MDL [2]. The MDLs were either equal to or below the guideline levels. Therefore these substances are considered to not be of concern and have been screened out.

Results of the initial screening assessment can be found in Table 4-14. As all VOCs were below detection limits, they have not been included in this table.

Table 4-14: Soil Screening Results

Parameter	Units	Maximum Concentration	MOECC Table 1 SCS	MOECC Table 3 SCS	CCME	Final Screening Criteria	Carry Forward to Tier 2
PHC F1 (C6-C10 less BTEX)	µg/g dw	10	25	55	320	320	No
PHC F2 (>C10-C16)	µg/g dw	68	10	230	260	260	No
PHC F3 (>C16-C34)	µg/g dw	170	240	1700	1700	1700	No
PHC F4 (>C34)*	µg/g dw	520	120	3300	3300	3300	No
Antimony	µg/g dw	0.57	1.3	40	40	1.3	No
Arsenic	µg/g dw	7	18	18	12	12	No
Barium	µg/g dw	71	220	670	2000	220	No
Beryllium	µg/g dw	0.63	2.5	8	8	2.5	No
Boron (Hot Water Soluble)	µg/g dw	1.1	NV	2	NV	2	No
Cadmium	µg/g dw	0.94	1.2	1.9	22	1.2	No
Chromium	µg/g dw	22	70	160	87	70	No
Chromium VI	µg/g dw	0.2	0.66	8	1.4	0.66	No
Cobalt	µg/g dw	9.1	21	80	300	21	No
Copper	µg/g dw	31	92	230	91	91	No
Lead	µg/g dw	23	120	120	600	120	No
Manganese	µg/g dw	1400	1400	NV	NV	1400	No – see discussion
Mercury	µg/g dw	0.2	0.27	3.9	50	0.27	No
Molybdenum	µg/g dw	1.0	2	40	40	2	No
Nickel	µg/g dw	19	82	270	50	50	No
Selenium	µg/g dw	0.84	1.5	5.5	2.9	1.5	No
Silver	µg/g dw	0.2	0.5	40	40	0.5	No
Thallium	µg/g dw	0.2	1	3.3	1	1	No
Vanadium	µg/g dw	44	86	86	130	86	No
Zinc	µg/g dw	140	290	340	360	290	No

Parameter	Units	Maximum Concentration	MOECC Table 1 SCS	MOECC Table 3 SCS	CCME	Final Screening Criteria	Carry Forward to Tier 2
Sodium Adsorption Ratio	µg/g dw	3.7	2.4	12	12	2.4	**Yes**
Boron (Total)	µg/g dw	14	36	120	NV	36	No
Uranium	µg/g dw	0.97	2.5	33	300	2.5	No
Dioxins and Furans, TEQ	pg/g dw	23.3	7.0	99.0	4.0	4.0	**Yes**

*PHC criteria were taken from MOECC Table 3 SCS and are appropriate to use for SARs as they were developed by the CCME. Other values are taken from MOECC Table 1 SCS and are appropriate for SARs.

The maximum measured manganese concentration is equal to the MOECC Table 1 SCS, which is considered to be background. Therefore it is not considered a COPC.

Therefore, the soil contaminants listed in Table 4-15 are considered to be COPCs and will be carried forward to the Tier 2 assessment:

Table 4-15: Soil COPCs

COPC	Maximum Concentration
Sodium Adsorption Ratio	3.7 µg/g dw
Dioxins and Furans, TEQ	23.3 pg/g

4.3.2.4 Surface Water

Sampling of surface water concentrations was performed as part of the WWMF baseline monitoring studies, for normal conditions as well as stormwater monitoring for total suspended solids (TSS). Baseline sampling points are:

1. SRD-1 (Figure 2-11);
2. SRD-4 (Figure 2-14);
3. GS-1 (Figure 2-16);
4. WTL-1 (Figure 2-15); and,
5. WD-4 (Figure 2-17).

Sampling of surface water in the SRD was also performed as part of the EMP. Sampling points for the EMP are:

1. SRD-2: Equivalent to baseline sampling (Location C) (Figure 2-12);
2. GS-1: Equivalent to baseline sampling Location D; and,
3. SRD-3: Equivalent to baseline sampling Location E (Figure 2-13).

Locations for baseline sampling for both surface water and sediment can be found in Figure 4-4.

Environmental concentrations in surface water were screened against PWQO [89] and CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life [88] for freshwater. For substances that did not have a PWQO or CCME guideline, the MOE Aquatic Protection Values (APV) [65] and the BC MOE Water Quality Guidelines were consulted [96].

For a number of substances, particularly PHCs and VOCs, concentrations were non-detect (i.e., <RDL). The RDLs were below guideline levels, where available. Therefore these substances are considered to not be of concern and have been screened out. Results of the initial screening assessment can be found in Table 4-16 for most contaminants, and in Table 4-17 for ammonia. The stormwater monitoring data has been included in Table 4-18 for information only. A summary of surface water monitoring data can be found in Appendix G.

Table 4-16: Surface Water Screening Results

Parameter	Unit	Maximum Concentration	PWQO	CCME (long term)	MOE APV	BC MOE	Final Screening Criteria	Carry Forward to Tier 2
PHC F2 (>C10 – C16)	µg/L	100			17*		17	No, see discussion
Dissolved Chloride	µg/L	460000		120000			120000	**Yes**
Aluminum	µg/L	561		100			100	**Yes**
Aluminum (clay-free)	µg/L	24	75				24	No
Antimony	µg/L	0.678	20				20	No
Arsenic	µg/L	1	5	5			5	No
Barium	µg/L	50.5			2300		230	No
Beryllium	µg/L	<0.05	11^				11	No
Bismuth	µg/L	<0.025						No
Boron	µg/L	66.5	200	1500			200	No
Cadmium	µg/L	0.016	0.1	0.17-0.37^			0.1	No
Calcium	µg/L	95233						No, see discussion
Dissolved Calcium	µg/L	100000						No, see discussion
Cesium	µg/L	<0.25						No; not detected
Chromium	µg/L	2			64		64	No
Cobalt	µg/L	1	0.9				0.9	**Yes**
Copper	µg/L	5	5	2-4^			2	**Yes**
Iron	µg/L	1440	300	300			300	**Yes**
Lead	µg/L	2.3	5, 3[i]	2.17-7^			2.17	No, see discussion
Lithium	µg/L	3						No, see discussion
Magnesium	µg/L	30100						No, see discussion

Parameter	Unit	Maximum Concentration	PWQO	CCME (long term)	MOE APV	BC MOE	Final Screening Criteria	Carry Forward to Tier 2
Dissolved Magnesium	µg/L	32000						No, see discussion
Manganese	µg/L	323.3				931	931	No
Total Mercury – Low Level	µg/L	0.02		0.026			0.026	No
Molybdenum	µg/L	1.09	40	73			40	No
Nickel	µg/L	6	25	76.03-150^			25	No
Phosphorus	µg/L	291.7	30	10-30[r]			10	**Yes**
Potassium	µg/L	8606.7				373,000	373000	No
Selenium	µg/L	2	100	1			1	**Yes**
Silicon	µg/L	4345						No, see discussion
Silver	µg/L	0.005	0.1	0.1			0.1	No
Sodium	µg/L	299000			180000		180000	**Yes**
Strontium	µg/L	3570						**Yes**
Sulphur	µg/L	7733				218000	218000	No
Thallium	µg/L	0.012	0.3	0.8			0.3	No
Thorium	µg/L	<0.0001						No; not detected
Tin	µg/L	<1.0						No; not detected
Titanium	µg/L	8.7				2000	2000	No
Tungsten	µg/L	0.038	30				30	No
Uranium	µg/L	1.12	5	15			5	No
Vanadium	µg/L	1.2	6		20		6	No
Zinc	µg/L	103.3	30, 20[i]	30			20	**Yes**
Zirconium	µg/L	0.87	4				4	No

*Dissolved; [i]Interim value
^Equation based on hardness; [r]Range, based on trophic status

Table 4-17: Screening for Ammonia in Surface Water

		Apr-14					Jul-14					Oct-14				
Location		Duplicate Average	WWMF	WWMF	WWMF	Duplicate Average	WWMF	WWMF	Duplicate Average	Duplicate Average	WWMF	Duplicate Average	WWMF	WWMF	WWMF	Duplicate Average
Sample ID		SRD-1	SRD-4	GS-1	WTL-1	WD-4	SRD-1	SRD-4	GS-1	WTL-1	WD-4	SRD-1	SRD-4	GS-1	WTL-1	WD-4
Sampling Date (MM/DD/YY)			04/17/14	04/16/14	04/16/14		07/14/14	07/14/14			07/14/14		10/14/14	10/14/14	10/14/14	
Laboratory ID Number		(VP4123 and VP4128)	VP4124	VP4125	VP4126	(VP4127 and VP4129)	WS2383	WS2384	(WS2385 and WS2389)	(WS2386 and WS2389)	WS2387	(YA3841 and YA3846)	YA3842	YA3843	YA3844	(YA3845 and YA3847)
	Units															
Field Measurements																
Field Temperature	Celsius	5.35	3.18	4.03	1.46	9.69	19.87	17.01	28.84	18.37	21.82	13.37	13.59	14.78	13.15	15.61
Field pH	pH	7.49	7.20	8.48	7.43	8.00	6.99	7.34	7.75	7.45	7.80	7.32	7.31	7.40	6.99	7.68
Inorganics																
Total Ammonia-N	µg/L	0.29	0.18	0.42	0.29	0.1	0.08	0.09	0.07	0.09	0.08	0.08	0.08	0.09	0.56	0.11
Sample Specific CEQG as NH_3	µg/L	4.84	15.3	0.502	7.32	1.04	4.82	2.22	0.26	1.54	0.50	2.22	2.22	2.22	6.98	2.22
Sample Specific CEQG as N	µg/L	3.98	12.58	0.413	6.02	0.86	3.96	1.83	0.21	1.27	0.41	1.83	1.83	1.83	5.74	1.83
Exceedance		No	No	No, see discussion	No	No	No	No	No	No	No	No	No	No	No	No

Table 4-18: Baseline Monitoring Stormwater Results

					May-14					Nov-14				
Location					Duplicate Average	WWMF	WWMF	WWMF	Duplicate Average	WWMF	Duplicate Average	Duplicate Average	WWMF	WWMF
Sample ID					SRD-1	SRD-4	GS-1	WTL-1	WD-4	SRD-1	SRD-4	GS-1	WTL-1	WD-4
Sampling Date (MM/DD/YY)						05/14/14	05/14/14	05/14/14		11/9/14			11/9/14	11/9/14
Laboratory ID Number					(VY0189 and VY0190)	VY0186	VY0188	VY0187	(VY0185 and VY0191)	XN9325	(XN9322 and XN9327)	(XN9324 and XN9328)	XN9323	XN9326
	Units	RDL	PWQO	CEQG										
Total Suspended Solids	mg/L	1		Narrative	11	1	12	<	4	3	<	2	2	2

The CEQG values for ammonia presented in Table 4-17 are based on temperatures of 5°C intervals. The CEQG value (as NH_3) of 0.502 µg/L identified is based on a temperature of 5°C. At a temperature of 0°C, the CEQG increases to 0.616 µg/L. Given that the sample temperature was 4.03°C (which indicates the CEQG is slightly conservative), and that the CEQG is only exceeded by 1.7%, ammonia is not considered a COPC and will not be assessed further.

The fraction of the PHC F2 is based on the MOE assumptions used in establishing the groundwater standards, which are consistent with CCME 2008 values. Due to the large volatility of the aliphatic fractions, any PHCs present in surface water are likely to be dominated by the aromatic fraction, which are less toxic than the aliphatic fractions. A value of 78 µg/L would be considered protective of the aromatic fractions. Since PHC F2 was not detected, this substance is not considered to be of concern and will not be assessed further.

Calcium is a major component in surface water and concentrations can vary greatly. In the Great Lakes, calcium generally ranges from 13,000 to 40,000 µg/L [97]. Although calcium levels are higher than this range in the surface water samples at the WWMF, calcium is not considered a COPC. Calcium is an essential element for plant and animal life and is generally not considered to be toxic. In toxicity tests for chloride, the CCME has used calcium as the cation (i.e., $CaCl_2$) to ensure that effect concentrations are associated with the chloride anion and not with the cation [98]. In addition, as a component of water hardness, calcium has the effect of reducing toxicity associated with various metals. Therefore, calcium is not considered to be a COPC and will not be assessed further.

Lithium was detected at concentrations ranging from 0.79 to <2.5 µg/L, which is below background concentrations (i.e., lithium concentrations in Central Canada have been found to range from 1 to 7 µg/L, with most concentrations across Canada as <10 mg/L [99]). Additionally, lithium concentrations on site are below the US EPA freshwater screening benchmark of 14 µg/L [100]. As such, lithium is not considered a COPC.

Lead was identified at one sampling location (i.e., GS-1 in June, 2013 at 2.3 µg/L) at a concentration greater than the lowest hardness-based CCME guideline. The CCME guideline is 2.17 µg/L to 7 µg/L based on the range of hardness measured at the WWMF (i.e., 74 mg/L to 370 mg/L). Hardness is a function of calcium and magnesium concentrations. Based on the calcium and magnesium concentrations at GS-1 in June 2013, the water hardness was 315 mg/L, which results in a CCME guideline of 7 µg/L. As such, lead does not exceed the CCME guideline and is not considered a COPC.

Magnesium is naturally found in surface water and is an essential element for all organisms. In areas rich in magnesium-containing rocks, surface water can contain magnesium in the concentration range 10,000 to 50,000 µg/L. Surface water quality in Canada has identified that magnesium concentrations vary greatly with location and often with season. Concentrations were usually below 25 mg/L, although concentrations as high as 168 mg/L have been measured [101]. At a maximum concentration of 30,100 µg/L, magnesium is within naturally occurring concentrations. Additionally, magnesium concentrations on site are below the US EPA freshwater screening benchmark of 82,000 µg/L [100]. As such, magnesium is not considered a COPC.

Silicon is a basic nutrient in water and is observed naturally from the breakdown of silicate minerals in the process of weathering. Large amounts of silicon are present in surface water. Rivers generally contain 4000 µg/L of silicon [102]. Concentrations at the WWMF range from 199 – 4345 µg/L, with all but two samples measured below 3000 µg/L. Therefore, total silicon is not considered a COPC and will not be assessed further.

Surface Water COPCs in Lake Huron

As shown in Table 4-16 and discussed above, surface water COPCs were identified for the WWMF. To determine if surface water COPCs may be present off-site (i.e., in Lake Huron) as a result of discharges from the WWMF, a surface water concentration in Lake Huron was estimated (Table 4-19). The surface water concentration was estimated based on the maximum concentration leaving the WWMF measured during the baseline monitoring program (i.e., from sampling points SRD-4 and WD-4); the concentration in the lake has been conservatively assumed to be equal to this concentration measured on site, as dilution will occur in the lake.

Dissolved chloride, sodium, strontium, and zinc will be assessed further in the Tier 2 evaluation, as dissolved chloride is above the guideline level (with no dilution applied) and there is no guideline for strontium.

Table 4-19: Surface Water Screening for Estimated Lake Huron Concentrations

COPC	Concentration (µg/L)		Guidelines (µg/L)				Carry Forward to Tier 2
	Maximum Concentration Exiting Site (SRD-4 or WD-4)	Sampling Point	PWQO	CCME (long term)	MOE APV	Guideline	
Dissolved Chloride	420000	WD-4		120000		120000	**Yes**
Aluminum (total)	25.7	WD-4		100		100	No
Cobalt	0.071	SRD-4	0.9			0.9	No
Copper	0.98	WD-4	5	2-4^		2	No
Iron	288	SRD-4	300	300		300	No
Phosphorus	8.1	SRD-4	30	10-30		10	No
Selenium	0.2	WD-4	100	1		1	No
Sodium	245000	WD-4			180000	180000	**Yes**
Strontium	2300	SRD-4				-	**Yes**
Zinc	24.1	SRD-4	30, 20	30		20	**Yes**

^Based on the hardness of the water

Therefore, the surface water contaminants listed in Table 4-20 could not be screened out for on-site and (in the case of strontium) receptors in Lake Huron. They are considered to be COPCs and will be carried forward to the Tier 2 assessment.

Table 4-20: Surface Water COPCs

COPC	Maximum Concentration (µg/L)	
	On-site	Lake Huron
Dissolved Chloride (Cl)	460000	420000
Aluminum (total/clay-free)	561 / 24	
Cobalt	1	
Copper	5	
Iron	1440	
Phosphorus	291.7	
Selenium	2	
Sodium	299000	245000
Strontium	3570	2300
Zinc	103.3	24.1

4.3.2.5 Sediment

Sampling of sediment concentrations was performed as part of the WWMF baseline monitoring studies and as part of the EMP. Sampling locations are as described in Section 4.3.2.4. Baseline sampling points are:

1. SRD-1;
2. SRD-4;
3. GS-1;
4. WTL-1; and,
5. WD-4.

Sampling points for the EMP are:

1. SRD-2: Equivalent to baseline sampling Location C;
2. GS-1: Equivalent to baseline sampling Location D; and,
3. SRD-3: Equivalent to baseline sampling Location E.

Sediment sampling locations are shown on Figure 4-4.

For non-radiological parameters, screening of the sediment data was completed through the use of the federal and provincial guidelines. Specifically, CCME Canadian Sediment Quality Guidelines (SQGs) for the Protection of Aquatic Life [88] and the Ontario MOECC Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario [103] were used to determine sediment COPCs.

The CCME provides an Interim Sediment Quality Guideline (ISQG) and a Probable Effect Level (PEL) concentration which results in three ranges for the evaluation of non-radiological concentrations in sediment:

1. If contaminant concentrations in sediment are less than the SQG, then adverse biological effects are rare;
2. If contaminant concentrations in sediment are greater than the SQG but are less than the PEL, adverse biological effects occur occasionally; and,
3. If contaminant concentrations in sediment are greater than the PEL, adverse biological effects are frequent.

The CCME SQGs provide a nationally consistent benchmark; however, during their implementation, exceedances of SQGs must be evaluated in the context of naturally occurring background concentrations. Concerns associated with contaminant concentrations in sediment must be focused on those non-radiological substances with concentrations greater than what is expected to occur naturally.

The MOECC provides a Lowest Effect Level (LEL) and a Severe Effect Level (SEL) in the PSQGs for metals. The LEL is a "level of contamination that can be tolerated by the majority of the sediment-dwelling organisms". The SEL represents sediment concentrations over which are "likely to affect the health of sediment-dwelling organisms" [103].

For those non-radiological substances with CCME and/or MOECC guidelines the data were evaluated as follows:

1. If there was no exceedance of a LEL or the ISQG, the substance was not considered a COPC;
2. If the concentration was >LEL and <SEL or >ISQG and <PEL, the concentrations were evaluated to determine if they are likely to be naturally occurring; and
3. If the concentration was >SEL or >PEL, the substance was considered a COPC.

For substances without a CCME or MOECC guideline, additional screening values were identified which represent a no-effect level concentration (e.g., Effective Concentration where 10% of the maximal effect is observed (EC10), NOAEL, and No Observed Effect Concentration (NOEC)). The FCSAP Database of Guidelines [104] was used to obtain guideline values. Guidelines were obtained from this source for:

- Antimony [105];
- Barium [106];
- Cobalt [106];
- Molybdenum [106]; and
- Silver [107].

The guideline for antimony is taken from the US EPA Mid-Atlantic Ecological Risk Assessment Freshwater Sediment Screening Benchmarks. The guideline for antimony is an effect range lows, which is equivalent to the lower 10th percentile of the analyzed data.

The barium, cobalt, and molybdenum guidelines are from a paper published by the Netherlands National Institute of Public Health and the Environment. For barium, the sensitivity of freshwater species was examined. A hazardous concentration for which half the species or processes are not protected (HC_{50}) of 7.0x10^3 µg/L was determined for surface water; applying equilibrium partitioning results in a serious risk addition (SRA_{eco}) of 7.0x10^3 mg/kg for sediment, and a resulting maximal permissible addition (MPA) of 29 mg/kg. For cobalt, data from freshwater and marine species were combined. An HC_{50} of 8.1x10^2 µg/L was determined for surface water; applying equilibrium partitioning results in a SRA_{eco} of 3.2x10^3 mg/kg for sediment, and a resulting MPA of 12 mg/kg. For molybdenum, data from freshwater and marine species were combined. An HC_{50} of 68 mg/L was determined for surface water; applying equilibrium partitioning results in a SRA_{eco} of 23 g/kg for sediment, and a resulting MPA of 25 mg/kg [106].

The guideline of 0.57 µg/g for silver was taken from the State of Washington Department of Ecology's Development of Benthic Sediment Quality Values for Freshwater Sediments. The guideline represents a no acute or chronic adverse effect level. The State of Washington also provides a value of 1.7 µg/g which represents a minor adverse effect level [107].

A screening guideline for uranium was taken from the Predicted No-effect Concentration for freshwater benthos of 100 mg/kg. This concentration was derived using environmental monitoring data of uranium concentrations in sediment and co-occurring benthic invertebrate data. An LEL of 104 mg U/kg dry sediment was determined, and a Predicted No-effect Concentration of 100 mg U/kg dry sediment was recommended [108].

For substances that do not have screening values, or for those screened against an LEL or an ISQG, the data were evaluated to determine if the substances are likely to be naturally occurring based on data provided by the MOE [87], [109] and the Southern Ontario Stream Sediment Geochemistry Survey (2012) [110], as provided by the Ministry of Northern Development and Mines (MNDM). Twenty six sampling locations in the vicinity of the Bruce nuclear site were chosen from the MNDM data set, and the 98th percentile value for this dataset was used as the background concentration for onsite sediment.

If a contaminant concentration exceeded the LEL or the ISQG but was less than background concentrations, it was not considered to be a COPC.

The screening assessment for sediment contaminants is available in Table 4-21. A summary of sediment monitoring data can be found in Appendix G.

Table 4-21: Sediment Screening Results

Parameter	Unit	Maximum concentration	PSQG		CEQG		Background*	Alternative Guideline	Carry Forward to Tier 2
			LEL	SEL	ISQG	PEL		mg/kg dw	
Aluminum	mg/kg dw	12700					16952		No
Antimony	mg/kg dw	0.565					0.21	2	No
Arsenic	mg/kg dw	7.42	6	33	5.9	17	4 to 6.3		**Yes**
Barium	mg/kg dw	90.75					89	29	No – See Appendix E
Beryllium	mg/kg dw	0.764					0.77		No
Bismuth	mg/kg dw	0.465					0.18		No – See Appendix E
Boron	mg/kg dw	25.47					NV		No – See Appendix E
Cadmium	mg/kg dw	0.884	0.6	10	0.6	3.5	0.51 to 1		No – See Appendix E
Calcium	mg/kg dw	178500					>65000		No – See Appendix E
Cesium	mg/kg dw	0.918					0.78		No – See Appendix E
Chromium	mg/kg dw	25.1	26	110	37.3	90	26 to 31		No
Cobalt	mg/kg dw	7.52					10.8	12	No
Copper	mg/kg dw	156.5	16	110	35.7	197	16 to 25		**Yes**
Iron	mg/kg dw	17933	20000	40000		-	23462 – 30000		No
Lead	mg/kg dw	23.2	31	250	35	91	15 to 31		No
Lithium	mg/kg dw	15.67					19.9		No
Magnesium	mg/kg dw	40300					>14000		No – See Appendix E
Manganese	mg/kg dw	1190	460	1100			400 to 732		**Yes**
Mercury	mg/kg dw	0.18	0.2	2	0.17	0.486	0.07 to 0.2		No – See Appendix E
Molybdenum	mg/kg dw	26.2	-	-			0.50	25	**Yes**
Nickel	mg/kg dw	24	16	75			16 to 31		No
Phosphorus	mg/kg dw	787	600	2000			899		No
Potassium	mg/kg dw	2110					2465		No
Selenium	mg/kg dw	1.11					1.1		No
Silicon (as Si)	mg/kg dw	688					NV		No – See Appendix E

Parameter	Unit	Maximum concentration	PSQG		CEQG		Background*	Alternative Guideline	Carry Forward to Tier 2
			LEL	SEL	ISQG	PEL		mg/kg dw	
Silver	mg/kg dw	15.6					0.07 to 0.5	0.57	**Yes**
Sodium	mg/kg dw	1490					242		**Yes**
Strontium	mg/kg dw	1130					281		**Yes**
Sulphur	mg/kg dw	770					4737		No
Thallium	mg/kg dw	0.222					0.16		No – See Appendix E
Thorium	mg/kg dw	2.66					3.63		No
Tin	mg/kg dw	1.925					0.79		No – See Appendix E
Titanium	mg/kg dw	407					307		No – See Appendix E
Tungsten	mg/kg dw	0.359					0.1		**Yes**
Uranium	mg/kg dw	2.23					1.8	100	No
Vanadium	mg/kg dw	29.83					42		No
Zinc	mg/kg dw	730	120	820	123	315	65 to 120		**Yes**
Zirconium	mg/kg dw	4.74					6.9		No

*Background concentrations consist of levels from MOE Table 1 [87], MOE 2008 guidelines [109], and MNDM [110].

Some substances may exceed the MOECC LEL, but do not exceed the background concentrations and are therefore not considered to be COPCs. These substances include cadmium, mercury, nickel [109], phosphorus, and tin [110].

Other substances were identified within ranges that occur naturally. These substances include barium, boron, thallium, tin and titanium. These substances are not considered to be COPCs.

Some substances were not considered to be COPCs due to their lack of toxicity, including bismuth [111], calcium, magnesium, and silicon.

Cesium is not considered to be a COPC; the concentration in Table 4-21 is the single cesium sample which exceeds the guideline, and is thought to be an anomaly or to be associated with natural variability.

Additional information is given on the sediment screening in Appendix E for the contaminants that have been screened out.

As can be seen in Table 4-21, copper, manganese and zinc each have concentrations greater than the SEL or PEL; these contaminants are considered to be COPCs.

Copper, manganese, and zinc exceed the MOE Table 1 guidelines, developed using the species screening level concentration method as described above, with the species screening level concentration plotted in increasing concentration. For copper and zinc, there is data for 98 species. The 5^{th} percentile is calculated to represent the LEL and the 95^{th} percentile becomes the SEL. Anything greater than the SEL suggests that there is an exceedance of the tolerance level for the majority of species.

For copper, there is only one of 98 species that has a tolerance level greater than sediment concentrations observed at SRD-1 (the sampling point with the maximum sediment copper concentration). For zinc, there are ten of the 98 species that have a tolerance level greater than concentrations observed at SRD-1. At SRD-1, 11 taxa represented by 146 specimens were collected. Thus, it is probable that copper and zinc are not very bioavailable at this site.

For manganese, the only location with a sediment concentration greater than the MNDM background data are SRD-4 in spring. There are no species with a tolerance level as high as found in this sample (38 species considered; however, 12 taxa represented by 123 specimens were collected at SRD-4, which suggests the manganese was not very bioavailable). This elevated concentration may be seen in spring due to cation exchange from road salt mobilizing the manganese in soil. The waste disposal area south of Area 6 (Figure 2-3) may be a potential source of manganese.

Contaminants in sediment identified as COPC are listed in Table 4-22 and will be carried forward for further assessment (Tier 2).

Table 4-22: Sediment COPCs Carried forward for Tier 2 Assessment

COPC	Maximum Concentration (mg/kg dw)
Arsenic	7.42
Copper	156.5
Manganese	1190
Molybdenum	26.2
Silver	15.55
Sodium	1490
Strontium	1130
Tungsten	0.3585
Zinc	730

4.3.2.6 Screening Summary

The non-radiological COPCs that require further assessment are summarized in Table 4-23.

Table 4-23: Summary of COPCs Carried Forward for Tier 2 Assessment

COPC	Concentration		
	Surface Water (µg/L)	Sediment (mg/kg dw)	Soil
Dissolved Chloride (Cl)	460000 (on-site) 420000 (Lake Huron)	-	-
Dioxins and Furans, TEQ	-	-	23.3 pg/g
Sodium Adsorption Ratio	-	-	3.7 µg/g dw
Aluminum (total/clay-free)	561 / 24	-	-
Arsenic	-	7.42	-
Cobalt	1	-	-
Copper	5	156.5	-
Iron	1440	-	-
Manganese	-	1190	-
Molybdenum	-	26.2	-
Phosphorus	291.7	-	-
Selenium	2	-	-
Silver	-	15.55	-
Sodium	299000 (on-site) 245000 (Lake Huron)	1490	-
Strontium	3570 (on-site) 2300 (Lake Huron)	1130	-
Tungsten	-	0.3585	-

COPC	Concentration		
	Surface Water (µg/L)	Sediment (mg/kg dw)	Soil
Zinc	103.3 (on-site) 24.1 (Lake Huron)	730	-

4.3.3 Exposure Point Concentrations and Doses

Exposure estimates are provided below for receptors with complete exposure pathways. For most receptors, COPC concentrations in individual environmental media are used as the exposure point concentrations. The exception is for birds and mammals, for which the exposure point concentrations for all applicable media and pathways for a given COPC are used to calculate an exposure dose [2].

4.3.3.1 Terrestrial Plants and Invertebrates

For plant and invertebrate species, the COPC concentrations in environmental media are used as the exposure point concentrations. These receptors are relatively immobile and will be directly exposed to the COPC concentrations at their locations [2]. For non-SAR and SAR receptors, exposure point concentrations have been chosen based on the locations with the maximum COPC concentrations and potential exposure routes.

COPCs identified in soil include sodium adsorption ratio and dioxins and furans.

Sodium adsorption ratio, a measure of the sodium levels in soil, is only relevant in the context of assessing risk to terrestrial plants, as soil with high sodium levels is a poor environment for plant growth. A sodium adsorption ratio level exceeding background was identified at sampling location A4-2 (Figure 4-4) [87]. No plant SARs are present in location A4-2 of the WWMF; however, for the purposes of the EcoRA, it has been assumed that non-SAR plant species may be exposed to the sodium adsorption ratio at location A4-2, which represents the maximum level measured on-site.

Plant SARs have been identified on site outside of the area of active property use (i.e., A2-2, A4-1, and A4-2). The maximum concentration outside of these areas has been identified as 0.28 µg/g at A1-1.

The maximum sodium adsorption ratio exposure to terrestrial plants and invertebrates for both non-SARs and SARs based on their identified locations is shown in Table 4-24.

Table 4-24: Sodium Adsorption Ratio Exposure

Receptor	Sampling Point	Maximum Concentration (µg/g dw)
Non-SAR	A4-2	3.7
SAR	A1-1	0.28

The only sampling locations with dioxin and furan levels that exceeded MOE Table 1 levels [87] are A2-2 and A4-2 (Figure 4-4). Sampling location A2-2 is next to a building and storage containers, and is used as a road or driveway. No plant SARs were identified in potential Expansion Area 2, and there do not appear to be any plants near A2-2. Sampling point A4-2 is located in potential Expansion Area 4, which is currently used as a parking lot. This area does not support ecological receptors. However, for the purposes of the EcoRA, it has been assumed that non-SAR plant or invertebrate species may be exposed to the dioxin and furan concentrations at location A4-2 as this represents the maximum on-site concentration.

Plant SARs have been identified on site outside of the area of active property use (i.e., A2-2, A4-1, and A4-2). The maximum concentration outside of these areas has been identified as TEQ 4.3 at MSA-1.

The maximum dioxin and furan exposure to terrestrial plants and invertebrates is given in Table 4-25.

Table 4-25: Dioxin and Furan Exposure

Receptor	Sampling Point	Maximum Concentration (pg/g dw)
Non-SAR	A4-2	23.3
SAR	MSA-1	4.3

4.3.3.2 Aquatic Receptors

As identified in Table 4-23, a number of COPCs were identified in surface water. These COPCs require further evaluation in the context of potential risks to aquatic receptors. As identified in Table 4-4, external exposure (via immersion or direct contact) to surface water is the predominant exposure pathway for aquatic plants, aquatic invertebrates, fish and herpetofauna. The exposure concentrations to these receptor groups are considered to be the maximum concentrations measured. Concentrations in Lake Huron were assumed to be the maximum concentration leaving the site (i.e., from SRD-4 or WD-4). These levels are assumed to be a conservative estimate of the concentrations in Lake Huron and have been used to estimate the exposure concentrations to fish in Lake Huron. Exposure concentrations for both on-site and Lake Huron aquatic receptors are given in Table 4-26.

Table 4-26: Exposure Concentrations for Aquatic Receptors (Plants, Invertebrates, Fish and Herpetofauna)

Surface Water COPC	Exposure Concentration (µg/L)	
	On-Site Receptors	Lake Huron Receptors
Dissolved Chloride	460000	420000
Aluminum (total / clay-free)	561 / 24	-

Surface Water COPC	Exposure Concentration (µg/L)	
	On-Site Receptors	Lake Huron Receptors
Cobalt	1	-
Copper	5	-
Iron	1440	-
Phosphorus	291.7	-
Selenium	2	-
Sodium	299000	245000
Strontium	3570	2300
Zinc	103.3	24.1

The sodium, strontium, and zinc exposure concentrations for receptors in Lake Huron were compared to concentrations measured in MacPherson Bay between 2007 and 2009 for the DGR EA [112]. This has only been included for comparison, as this was performed as a means of verifying the estimated concentration. This comparison can be seen in Table 4-27.

Table 4-27: Estimated Exposure Concentration vs. DGR EA Measured Concentrations

Surface Water COPC	Lake Huron Receptors Estimated Exposure Concentration (µg/L)	MacPherson Bay Measured Concentration* [112] (µg/L)
Dissolved Chloride	420000	Not available
Sodium	245000	4500 – 140000 (29771)
Strontium	2300	120 – 1700 (477)
Zinc	24.1	<5 – 110 (22)

*Range of measured concentrations. Mean concentration given in parentheses.

Dissolved chloride was not measured as part of the DGR EA surface water sampling.

For sodium, the maximum measured concentration was less than the estimated concentration, though the two concentrations are on the same order of magnitude. However, this was the only measured sample in the DGR EA that resulted in a measurement on this order of magnitude; all other samples were measured at least one order of magnitude smaller. The average measured concentration reflects this; it is an order of magnitude smaller than the estimated concentration. Therefore, the sodium exposure concentration presented in Table 4-26 can be assumed to be a conservative estimation of the current concentration in Lake Huron.

For strontium, the maximum measured concentration was less than the estimated concentration; the mean concentration is one order of magnitude smaller than the estimated concentration. Therefore, the strontium exposure concentration presented in Table 4-26 can be assumed to be a conservative estimation of the current concentration in Lake Huron.

For zinc, the maximum measured concentration was greater than the estimated concentration; however, this was the only measured sample in the DGR EA that resulted in a measurement on this order of magnitude. All other samples yielded much smaller zinc concentrations, and the duplicate sample taken at the same time (May 2007) resulted in a much smaller zinc concentration (7 µg/L) which was more in line with the concentrations measured at other sampling times. Therefore the measured concentration of 110 µg/L may be anomalous. With this sample included, the average measured zinc concentration is very near to the estimated zinc concentration. If this concentration is not included, the maximum measured concentration was 16 µg/L, with the average measured concentration at 6.58 µg/L. The estimated concentration is on the same order of magnitude as this maximum measured concentration, though an order of magnitude larger than the average measured concentration. Given the full dataset, the zinc exposure concentration presented in Table 4-26 can be assumed to be a reasonable estimation of the current concentration in Lake Huron.

As identified in Table 4-22, a number of COPCs were identified in sediment. These COPCs require further evaluation in the context of potential risks to benthic invertebrates. Exposure concentrations to aquatic receptors from sediment COPCs is given in Table 4-22. Exposure to aquatic birds and mammals is also relevant, as discussed in Section 4.3.3.5.

4.3.3.3 Terrestrial Birds and Mammals

For wildlife, exposure to COPCs via relevant exposure pathways is determined by calculating an exposure dose (in mg/kg/d). Exposure doses can then be compared to reference doses reported in the literature. This approach assumes mechanisms of toxicity for substances are the same regardless of the method of intake.

The pathways that are considered to be complete for terrestrial mammals and birds are outlined in Figure 4-3 and Table 4-4; potential pathways include contact with soil and surface water, ingestion of soil (incidental), ingestion of surface water, and ingestion of biota. There are no complete pathways for exposure of terrestrial mammals and birds to sediment.

Exposure to surface water COPCs, either through immersion or ingestion, will be minimal for terrestrial mammals and birds in comparison to exposure to aquatic receptors, as the aquatic receptors receive continuous exposure. Therefore exposure to surface water COPCs is considered minimal and will not be assessed for terrestrial receptors.

Terrestrial mammals and birds are exposed to soil COPCs. Table 4-15 identifies sodium adsorption ratio and dioxins and furans as soil COPCs. Sodium adsorption ratio is only relevant to terrestrial plants, and therefore has not been examined.

Relatively mobile species (e.g., birds and mammals) move about the site and are exposed to a variety of contaminant concentrations. As a result, an exposure concentration other than the maximum can be employed in the exposure assessment. Where the number of samples analyzed and the number of detected concentrations are sufficient, a 95th upper confidence limit on the arithmetic mean is an appropriate exposure concentration. The number of soil samples and detections for dioxins and furans enabled the calculation of the upper confidence limit on the arithmetic mean.

The average concentrations of dioxins and furans in soil (as identified by a 95th upper confidence level of the mean) were 6.15 pg/g in June 2014 and 7.9 pg/g in August 2014. These concentrations average to 7 pg/g.

The uptake equations and concentrations in food items are provided in Table 4-28.

To calculate the exposure dose to the birds and mammals, body weight, food, and soil consumption rates were used. A summary of the exposure parameters for these receptors is provided in Table 4-29 for birds and Table 4-30 for mammals. All birds and mammals were assumed to be on site 100% of the time; this assumption is conservative as some species are migratory.

For the assessment of terrestrial COPCs to the bald eagle, 100% of the bald eagle's diet is assumed to be composed of terrestrial mammals and birds (Table 4-29). Since there is no overlap in the COPCs between the terrestrial and aquatic assessments, separate analyses is appropriate for the bald eagle. Combined with the assumption that the bald eagle is on site 100% of the time, the terrestrial exposure assessment results in a conservative exposure of the bald eagle to dioxins and furans.

Based on the exposure calculations and the exposure parameters provided in Table 4-28, Table 4-31 summarizes the estimated exposure dose for birds and mammals.

Table 4-28: Dioxin and Furan Concentrations in Food Items

Food Item	Uptake Equation	Soil Concentration (mg/kg)	Food Item Concentration (mg/kg dw)	Reference
Worms	ln(Ci) = 3.533 + 1.182 x ln(Cs)	7.00E-06	2.76E-05	[113]
Plants	Cp = 0.00628 x Cs	7.00E-06	4.40E-08	[114]
Mammals	ln(Cm) = 0.8113 + 1.0993 x ln(Cs)	7.00E-06	4.85E-06	[115]

Where:

Ci = concentration in invertebrates

Cs = concentration in soil

Cp = concentration in plants

Cm = concentration in the short-tailed shrew

Table 4-29: Exposure Parameters for Birds

Parameter	Red-Eyed Vireo	American Robin	Wild Turkey	Bald Eagle
Body weight (kg)	1.80E-02 [116]	7.90E-02 [79]	5.80E+00 [117]	4.70E+00 [79]
Food ingestion rate (kg wet food/d)~	1.40E-02	1.20E-01	6.70E-01	5.88E-01
Food ingestion rate (kg wet food/kg wet BW/d)	7.78E-01*	1.52E+00 [79]	1.16E-01*	1.25E-01*
Food ingestion rate (kg dry food/kg wet BW/d)^	1.24E-01	2.42E-01	1.76E-02	4.00E-02
Soil Ingestion Rate (kg dw/kg wet BW/d)	1.11E-02†	2.29E-02‡	3.21E-03†	0.00E+00
Diet	Insects, some fruit	Earthworms and plants	Fruit, seeds, foliage, insects	Fish, Mammals and Birds
Fraction of Time on-Site	1	1	1	1
Fraction of Food in Diet				
Plants	0.1	0.1	0.8	0
Earthworms	0.9	0.9	0.2	0
Mammals and Birds	0	0	0	1
Aquatic Plants	0	0	0	0
Aquatic Invertebrates	0	0	0	0
Fish	0	0	0	0

BW – body weight
ww - wet weight
dw – dry weight
~Data from the radiological model; see Table D-2 in Appendix D.
*Calculated: Food ingestion rate (kg wet food/d) / Body weight
^Calculated: Food ingestion rate (kg wet food/kg wet BW/d)*Σ[(1-% moisture in food item)*fraction of food item in diet]
†Calculated: dry soil intake / body weight
‡Calculated based on method identified in [79] where consumption is proportional to earthworm consumption and 10.4% soil ingestion is associated with 99% earthworms. Earthworm consumption is set at 90%, resulting in a soil consumption of 9.5%. Multiply 0.095 with dry food ingestion rate.

Table 4-30: Exposure Parameters for Mammals

Parameter	Short-tailed Shrew	Little Brown Bat	White Tailed Deer	Red Fox
Body weight (kg)	1.50E-02 [65]	7.50E-03 [117]	8.00E+01 [118]	3.80E+00 [79]
Food ingestion rate (kg wet food/d) ~	1.30E-02	4.70E-03	1.10E+01	3.10E-01
Food ingestion rate (kg wet food/kg wet BW/d)*	8.67E-01	6.27E-01	1.38E-01	8.16E-02
Food ingestion rate (kg dry food/kg wet BW/d)^	1.39E-01	1.00E-01	2.06E-02	1.04E+00
Soil Ingestion Rate (kg dw/kg wet BW/d)†	6.00E-03	0.00E+00	8.25E-04	6.84E-04
Diet	Insects, Larvae, Slugs, Snails and Earthworms	Flying insects	Buds, twigs, grasses and fruits	Small Mammals, Invertebrates, Birds and Plants
Fraction of Time on-Site	1	1	1	1
Fraction of Food in Diet				
Plants	0	0	1	0.15
Earthworms	1	1‡	0	0
Mammals and Birds	0	0	0	0.85
Aquatic Plants	0	0	0	0
Aquatic Invertebrates	0	0	0	0
Fish	0	0	0	0

BW – body weight
ww - wet weight
dw – dry weight
~Data from the radiological model; see Table D-2 in Appendix D.
*Calculated: Food ingestion rate (kg wet food/d) / Body weight
^Calculated: Food ingestion rate (kg wet food/kg wet BW/d)*∑[(1-% moisture in food item)*fraction of food item in diet]†Calculated: dry soil intake / body weight
‡Due to availability of information, earthworms are used as a surrogate for assessing exposure to non-radionuclides through the ingestion of insects.

Table 4-31: Dioxin and Furan Exposure Estimates

Receptor	Dose from Soil (mg/kg/day)	Dose from Food Ingestion (mg/kg/day)	Average Daily Dose (mg/kg/day)
Red-Eyed Vireo	7.78E-08	3.07E-06	3.15E-06
American Robin	1.61E-07	6.01E-06	6.17E-06
Wild Turkey	2.24E-08	9.76E-08	1.20E-07
Bald Eagle	0.00E+00	1.94E-07	1.94E-07
Short-tailed Shrew	4.20E-08	3.83E-06	3.87E-06
Little Brown Bat	0.00E+00	2.77E-06	2.77E-06
White Tailed Deer	5.78E-09	9.07E-10	6.68E-09
Red Fox	4.79E-09	4.27E-06	4.28E-06

4.3.3.4 Herpetofauna – Soil Exposure

Exposure associated with COPCs in the aquatic habitat is addressed in Section 4.3.3.2. In the terrestrial habitat, the only COPC is dioxins and furans in soil. Exposure to herpetofauna is not quantitatively assessed due to limitations in exposure characteristics. Herpetofauna will be assessed qualitatively.

4.3.3.5 Aquatic Birds and Mammals

The surface water, sediment and plant concentrations used in the exposure model were based on maximum concentrations, with the exception of values for iron and aluminum. For iron and aluminum, the exposure concentrations are based on a 95th Upper Confidence Limit on the Mean (UCLM), or, where the number of data points was less than 8, a 90th percentile.

In the evaluation of exposure, it is important to take into consideration exposure durations as well as the area in which exposure may occur. An evaluation of data collected from 2014 was used in the exposure assessment as this was considered most representative of the baseline condition. In addition, the data sets were evaluated with and without the inclusion of data from the West Ditch. This approach was undertaken due to the separation of the West Ditch from the other surface water bodies.

For surface water, a 95th UCLM or 90th percentile was calculated using the April/May data, April/May/July data and April/May/July/October data, with all sampling locations and without samples from the West Ditch. The most conservative value was used in the exposure assessment (i.e., April/May data without the West Ditch for aluminum and April/May/July data without West Ditch for iron).

For sediment, a 95th UCLM or 90th percentile was calculated using the April/May data and the April/May/October data, with all sampling locations and without samples from the West Ditch. The most conservative value was used in the exposure assessment (i.e., April/May data without the West Ditch for aluminum and iron).

Concentrations in both surface water and sediment were included for all surface water and sediment COPCs, regardless of which medium the contaminant was identified as a COPC.

For COPCs measured in plants (cattails), a 95th UCLM or 90th percentile was calculated using all sampling locations and without samples from the West Ditch. The most conservative value (i.e., the 90th percentile for locations excluding the West Ditch) was used in the exposure assessment.

The uptake factors and concentrations in food items are provided in Table 4-32, Table 4-33, and Table 4-34 for aquatic plants, aquatic insects, and fish. To determine the estimated concentration in each food item, the surface water concentration is multiplied by the uptake factor for each COPC. The uptake factors were obtained from the references included in the "Reference" column. The resulting estimated concentrations are used in calculations of the exposure dose to the mallard, bald eagle, and muskrat.

The mallard duck and muskrat are aquatic receptors that use aquatic plants as a food source. For the muskrat, measured concentrations in cattails (as described above) was used in the exposure assessment as cattails are the muskrat's primary food source. The mallard duck does not use the cattail as a primary food source. To identify concentration of COPCs in aquatic plants (other than cattails), a concentration was estimated using a surface water to aquatic vegetation uptake factor. The mallard duck and muskrat also eat aquatic invertebrates. In the calculation of concentrations in aquatic insects, a surface water to aquatic insect uptake factor was used.

To calculate the exposure dose to the mallard, bald eagle, and muskrat, body weight, food, and soil/sediment consumption rates were used. A summary of the exposure parameters for these receptors is provided in Table 4-35.

The bald eagle is an apex predator for both the terrestrial and aquatic food chains; therefore both the terrestrial and aquatic pathways are applicable to the bald eagle. For the assessment of aquatic COPCs, fish are assumed to make up 100% of the bald eagle's diet (Table 4-35). Because there is no overlap in COPCs between the terrestrial and aquatic assessments, separate analyses is appropriate for the bald eagle. This results in a conservative exposure to the aquatic COPCs.

Table 4-32: Calculation of COPC Concentrations in Aquatic Plants

COPC	Estimated Surface Water Concentration (mg/L)	Uptake Factor	Estimated Concentration (mg/kg ww)	Estimated Concentration (mg/kg dw)	Measured Concentration in Aquatic Plants (mg/kg dw)	Reference
Aluminum	1.60E-01	833	1.33E+02	8.33E+02	3.30E+02	[119]
Arsenic	1.00E-03	293	2.93E-01	1.83E+00	9.00E-01	[119]
Chloride	4.60E+02	50	2.30E+04	1.44E+05	1.44E+05	[31]
Cobalt	1.00E-03	6000	6.00E+00	3.75E+01	3.21E-01	[31]
Copper	5.00E-03	541	2.71E+00	1.69E+01	2.68E+00	[119]
Iron	3.43E-01	3100	1.06E+03	6.65E+03	8.09E+02	[31]
Manganese	3.23E-01	4400	1.42E+03	8.89E+03	8.84E+01	[31]
Molybdenum	1.09E-03	1	1.09E-03	6.81E-03	1.60E-01	[31]
Selenium	2.00E-03	1847	3.69E+00	2.31E+01	2.00E-01	[119]
Silver	5.00E-06	10696	5.35E-02	3.34E-01	2.10E-01	[119]
Sodium	2.99E+02	18	5.38E+03	3.36E+04	1.65E+03	[31]
Strontium	3.57E+00	370	1.32E+03	8.26E+03	3.17E+01	[31]
Tungsten	3.80E-05	NV	NC	NC	NV	NA
Zinc	1.03E-01	2175	2.25E+02	1.40E+03	1.82E+01	[119]

Table 4-33: Calculation of COPC Concentrations in Aquatic Insects

COPC	Estimated Surface Water Concentration (mg/L)	Uptake Factor	Estimated Concentration (mg/kg ww)	Estimated Concentration (mg/kg dw)	Reference
Aluminum	1.60E-01	547.5	8.76E+01	5.15E+02	[120]
Arsenic	1.00E-03	73	7.30E-02	4.29E-01	[119]
Chloride	4.60E+02	140	6.44E+04	3.79E+05	[31]
Cobalt	1.00E-03	110	1.10E-01	6.47E-01	[31]
Copper	5.00E-03	3718	1.86E+01	1.09E+02	[119]
Iron	3.43E-01	2800	9.60E+02	5.65E+03	[31]
Manganese	3.23E-01	690	2.23E+02	1.31E+03	[31]
Molybdenum	1.09E-03	3.6	3.92E-03	2.31E-02	[31]
Selenium	2.00E-03	240	4.80E-01	2.82E+00	[31]
Silver	5.00E-06	298	1.49E-03	8.76E-03	[119]
Sodium	2.99E+02	7.3	2.18E+03	1.28E+04	[31]
Strontium	3.57E+00	240	8.57E+02	5.04E+03	[31]
Tungsten	3.80E-05	10	3.80E-04	2.24E-03	[121]
Zinc	1.03E-01	4578	4.73E+02	2.78E+03	[119]

Table 4-34: Calculation of COPC Concentrations in Fish

COPC	Estimated Surface Water Concentration (mg/L)	Uptake Factor	Estimated Concentration (mg/kg ww)	Estimated Concentration (mg/kg dw)	Reference
Aluminum	1.60E-01	2.7	4.32E-01	1.73E+00	[119]
Arsenic	1.00E-03	114	1.14E-01	4.56E-01	[119]
Chloride	4.60E+02	47	2.16E+04	8.65E+04	[31]
Cobalt	1.00E-03	54	5.40E-02	2.16E-01	[31]
Copper	5.00E-03	710	3.55E+00	1.42E+01	[119]
Iron	3.43E-01	240	8.23E+01	3.29E+02	[31]
Manganese	3.23E-01	240	7.76E+01	3.10E+02	[31]
Molybdenum	1.09E-03	460	5.01E-01	2.01E+00	[31]
Selenium	2.00E-03	129	2.58E-01	1.03E+00	[119]
Silver	5.00E-06	87.71	4.39E-04	1.75E-03	[119]
Sodium	2.99E+02	84	2.51E+04	1.00E+05	[31]
Strontium	3.57E+00	2	7.14E+00	2.86E+01	[31]
Tungsten	3.80E-05	1200	4.56E-02	1.82E-01	[121]
Zinc	1.03E-01	2059	2.13E+02	8.51E+02	[119]

Table 4-35: Exposure Parameters for Aquatic Birds and Mammals

Parameter	Mallard Duck	Bald Eagle	Muskrat
Body weight (kg)	1.20E+00 [79]	4.70E+00 [79]	1.00E+00 [79]
Food ingestion rate (kg wet food/d)~	2.50E-01	5.88E-01	3.60E-01
Food ingestion rate (kg wet food/kg wet BW/d)*	2.08E-01	1.25E-01	3.60E-01
Food ingestion rate (kg dry food/kg wet BW/d)^	3.91E-02	3.13E-02	1.45E-01
Sediment ingestion rate (kg dw/kg wet BW/d)	1.42E-03†	0.00E+00	2.40E-03†
Water ingestion rate (L/kg BW/d)	6.00E-02 [79]	4.00E-02 [79]	1.00E-01 [79]
Diet	Aquatic plants and invertebrates	Fish, Mammals and Birds	Aquatic vegetation, invertebrates and fish.
Fraction of Time on-Site	1	1	1
Fraction of Food in Diet			
Plants	0	0	0
Earthworms	0	0	0
Mammals and Birds	0	0	0
Aquatic Plants	0.25	0	0.98
Aquatic Invertebrates	0.75	0	0.02
Fish	0	1	0

BW – body weight
~Data from the radiological model; see Table D-2 in Appendix D.
*Calculated: Food ingestion rate (kg wet food/d) / Body weight
^Calculated: Food ingestion rate (kg wet food/kg wet BW/d)*Σ[(1-% moisture in food item)*fraction of food item in diet]
†Calculated: Dry soil intake / body weight

Based on the exposure calculations and the exposure parameters provided above, Table 4-36, Table 4-37, and Table 4-38 summarize the estimated exposure dose for aquatic birds and aquatic mammals.

In Table 4-36, Table 4-37, and Table 4-38 below, the dose from sediment was determined by multiplying the exposure concentration in sediment by the soil ingestion rate (Table 4-35). Similarly, the dose from water ingestion was determined by multiplying the estimated concentration in surface water by the water ingestion rate. The dose from food ingestion was calculated by multiplying the dry weight food ingestion rate for the receptor by the fraction of a food source (such as plants) in the receptor's diet (Table 4-35) and the estimated COPC concentration in that food source (Table 4-32, Table 4-33, and Table 4-34); the total dose from food ingestion is found by adding the exposure values from each individual food source. The average daily dose to each receptor is a sum of the doses from sediment, water, and food ingestion.

Table 4-36: Mallard Duck Exposure Estimates

COPC	Estimated Concentration in Surface Water (mg/L)	Exposure Concentration in Sediment (mg/kg dw)	Mallard Duck			
			Dose from Sediment (mg/kg dw/day)	Dose from Water Ingestion (mg/kg/day)	Dose from Food Ingestion (mg/kg dw/day)	Average Daily Dose (mg/kg/day)
Aluminum	1.60E-01	1.13E+04	1.60E+01	9.60E-03	2.32E+01	3.92E+01
Arsenic	1.00E-03	7.42E+00	1.05E-02	6.00E-05	3.05E-02	4.10E-02
Chloride	4.60E+02	NV	NV	2.76E+01	1.25E+04	1.25E+04
Cobalt	1.00E-03	7.52E+00	1.07E-02	6.00E-05	3.85E-01	3.96E-01
Copper	5.00E-03	1.57E+02	2.22E-01	3.00E-04	3.37E+00	3.59E+00
Iron	3.43E-01	1.66E+04	2.35E+01	2.06E-02	2.30E+02	2.54E+02
Manganese	3.23E-01	1.19E+03	1.69E+00	1.94E-02	1.25E+02	1.27E+02
Molybdenum	1.09E-03	2.62E+01	3.71E-02	6.54E-05	7.43E-04	3.79E-02
Selenium	2.00E-03	1.11E+00	1.57E-03	1.20E-04	3.08E-01	3.10E-01
Silver	5.00E-06	1.56E+01	2.20E-02	3.00E-07	3.52E-03	2.56E-02
Sodium	2.99E+02	1.49E+03	2.11E+00	1.79E+01	7.05E+02	7.25E+02
Strontium	3.57E+00	1.13E+03	1.60E+00	2.14E-01	2.28E+02	2.30E+02
Tungsten	3.80E-05	3.59E-01	5.08E-04	2.28E-06	NC	NC
Zinc	1.03E-01	7.30E+02	1.03E+00	6.20E-03	9.52E+01	9.63E+01

Table 4-37: Bald Eagle Exposure Estimates

COPC	Estimated Concentration in Surface Water (mg/L)	Exposure Concentration in Sediment (mg/kg dw)	Bald Eagle		
			Dose from Water Ingestion (mg/kg/day)	Dose from Food Ingestion (mg/kg/day)	Average Daily Dose (mg/kg/day)
Aluminum	1.60E-01	1.13E+04	6.40E-03	5.40E-02	6.04E-02
Arsenic	1.00E-03	7.42E+00	4.00E-05	1.43E-02	1.43E-02
Chloride	4.60E+02	NV	1.84E+01	2.70E+03	2.72E+03
Cobalt	1.00E-03	7.52E+00	4.00E-05	6.76E-03	6.80E-03
Copper	5.00E-03	1.57E+02	2.00E-04	4.44E-01	4.44E-01
Iron	3.43E-01	1.66E+04	1.37E-02	1.03E+01	1.03E+01
Manganese	3.23E-01	1.19E+03	1.29E-02	9.71E+00	9.72E+00
Molybdenum	1.09E-03	2.62E+01	4.36E-05	6.27E-02	6.28E-02
Selenium	2.00E-03	1.11E+00	8.00E-05	3.23E-02	3.24E-02
Silver	5.00E-06	1.56E+01	2.00E-07	5.49E-05	5.51E-05
Sodium	2.99E+02	1.49E+03	1.20E+01	3.14E+03	3.15E+03
Strontium	3.57E+00	1.13E+03	1.43E-01	8.93E-01	1.04E+00
Tungsten	3.80E-05	3.59E-01	1.52E-06	5.70E-03	5.71E-03
Zinc	1.03E-01	7.30E+02	4.13E-03	2.66E+01	2.66E+01

Table 4-38: Muskrat Exposure Estimates

COPC	Estimated Concentration in Surface Water (mg/L)	Exposure Concentration in Sediment (mg/kg dw)	Muskrat			
			Dose from Sediment (mg/kg dw/day)	Dose from Water Ingestion (mg/kg/day)	Dose from Food Ingestion (mg/kg/day)	Average Daily Dose (mg/kg/day)
Aluminum	1.60E-01	1.13E+04	2.70E+01	1.60E-02	4.40E+01	7.11E+01
Arsenic	1.00E-03	7.42E+00	1.78E-02	1.00E-04	1.18E-01	1.35E-01
Chloride	4.60E+02	NV	0.00E+00	4.60E+01	1.96E+04	1.96E+04
Cobalt	1.00E-03	7.52E+00	1.80E-02	1.00E-04	4.32E-02	6.14E-02
Copper	5.00E-03	1.57E+02	3.76E-01	5.00E-04	6.35E-01	1.01E+00
Iron	3.43E-01	1.66E+04	3.98E+01	3.43E-02	1.20E+02	1.59E+02
Manganese	3.23E-01	1.19E+03	2.86E+00	3.23E-02	1.49E+01	1.78E+01
Molybdenum	1.09E-03	2.62E+01	6.29E-02	1.09E-04	2.08E-02	8.37E-02
Selenium	2.00E-03	1.11E+00	2.66E-03	2.00E-04	3.33E-02	3.62E-02
Silver	5.00E-06	1.56E+01	3.73E-02	5.00E-07	2.72E-02	6.45E-02
Sodium	2.99E+02	1.49E+03	3.58E+00	2.99E+01	2.48E+02	2.81E+02
Strontium	3.57E+00	1.13E+03	2.71E+00	3.57E-01	1.74E+01	2.05E+01
Tungsten	3.80E-05	3.59E-01	8.60E-04	3.80E-06	NC	NC
Zinc	1.03E-01	7.30E+02	1.75E+00	1.03E-02	9.70E+00	1.15E+01

4.3.4 Effects Assessment - Toxicological Benchmarks

Toxicological benchmarks, known as toxicity reference values (TRVs), are provided for any non-radiological COPCs identified through the screening process and carried into the PQRA.

The TRVs are obtained from toxicological studies with measurement endpoints relevant to the assessment endpoints and typically include survival, growth, and reproduction. The TRVs are selected to correspond to the lowest exposure levels (e.g., LOAELs, Lowest Observed Effect Concentrations (LOECs), effective dose for 20% of the exposed population (ED_{20}), or effective concentration for 20% or 25% of the maximum effect (EC_{20} or EC_{25})). An exception exists where a SAR is present, at which point the TRV to assess these receptors is selected to represent a NOAEL.

Where the toxicological information does not include a toxicity endpoint equivalent to a low exposure level (e.g., EC_{20} or EC_{25}), an uncertainty factor is applied to approximate these values. For example, a factor of 2 is applied to a chronic EC_{50} and a factor of 4 is applied to a chronic LC_{50}. For receptors at the community level, available toxicological information for a sensitive member of the community has been used.

Benchmark values are obtained from regulatory organizations (such as the MOECC, British Columbia MOE, and US EPA) in addition to documents prepared for the US Department of Energy in support of risk assessment ([122], [123], [124], [125]). Where appropriate, additional resources were used to obtain benchmark values.

4.3.4.1 Terrestrial Plants and Invertebrates

The MOECC has defined guidelines for sodium adsorption ratio and dioxin and furan concentrations in soil which are considered protective of ecological receptors which are non-SARs (i.e., Table 3 values used to represent the soil benchmark values) [87]. The Table 1 values are background concentrations which are considered protective of SARs and are used to represent a soil benchmark value for SARs. These benchmarks are given in Table 4-39.

Table 4-39: Soil COPC Effect Concentrations

Soil COPC	Unit	Receptor	Sampling Point	Effect Concentration
Sodium Adsorption Ratio	µg/g	Non-SAR	A4-2	12
		SAR	A1-1	2.4
Dioxins and Furans	pg/g	Non-SAR	A4-2	99
		SAR	MSA-1	7

Sampling point A4-2 is located in potential Expansion Area 4, which is currently used as a parking lot. This area does not support ecological receptors. Therefore the MOE Table 3 value can be applied [87].

Plant SARs have been identified on site outside of the area of active property use (A2-2, A4-1, and A4-2). These values are screened against the MOE Table 1 standard, as this is considered to be protective of SARs [87].

4.3.4.2 Surface Water

The TRVs for surface water COPCs and the applicable receptors are given in Table 4-40 for aquatic plants and invertebrates, Table 4-41 for fish, and Table 4-42 for herpetofauna.

The following should be noted for certain TRVs:

- Selenium: Selenium is bioaccumulative. It also represents a challenge in terms of evaluating toxicity as it is a required nutrient but becomes toxic at concentrations which are only slightly higher than background in field studies. In field studies, the density of benthic invertebrates (isopods and tubificid worms) and algal diversity has been identified as being reduced at 0.01 mg/L. Fish and amphibians are considered to be more sensitive receptor groups than plants and invertebrates. There is limited data on the effect of selenium on amphibians; however, is it speculated that they will respond similarly to fish. Chronic exposure by fish can result in reproductive and non-reproductive effects, with the majority of research supporting an effects threshold of 0.002 mg/L. Using a weight of evidence approach the BC MOE has established a guideline of 0.002 mg/L which is considered protective of all aquatic life (including birds and mammals). This takes into consideration exposure to surface water, in addition to exposure through the food web. An alert concentration of 0.001 mg/L is proposed due to a high bioaccumulation potential in some environments [126].
- Phosphorus: Toxicity benchmarks are not established for phosphorus as it is not considered toxic to aquatic organisms at levels and forms present in the environment. However, the addition of phosphorous to an aquatic system can result in increased plant and algal growth which can result in negative effects to the ecosystem. Given the low flow drainage and depositional nature of the surface water at the WWMF, the surface water bodies are considered to have meso-trophic to eutrophic characteristics. Meso-eutrophic to eutrophic water bodies have phosphorous concentrations in the range of 0.02 to 0.1 mg/L [127].
- Sodium: With the exception of aquatic invertebrates, toxicity benchmarks were not identified for the aquatic receptor groups. In aquatic toxicity studies, the toxicity of sodium salts is primarily attributed to the corresponding anion [128] rather than sodium, which is a cation. In the identification of aquatic toxicity values for sodium by the MOE [65], chloride was used as a substitute. This is considered a conservative approach.

Table 4-40: Surface Water TRVs for Aquatic Plants and Invertebrates

Parameter	Receptor	TRV (µg/L)	Endpoint	Reference
Chloride	Aquatic Invertebrates	421,000	*Daphnia magna* 21-day EC_{25}	[98]
	Benthic Invertebrates	121,000	60-80 day LOEC Fingernail clam	[98]
	Aquatic Plants and Algae	1,171,000	96-hour maximum acceptable toxicant concentration (MATC) for Duckweed	[98]
Aluminum	Aquatic Invertebrates	320	*Daphnia magna* reproductive impairment in 16% of the test species (EC_{16})	[129]
	Benthic Invertebrates	416	Midge larvae (*Tanytarsus dissimilis*) $LC_{37/2}$	[120]
	Aquatic Vegetation	230	Lowest chronic value (LCV) for green alga based on a 4-day EC_{50} divided by an uncertainty factor of 2.	[120]
Cobalt	Aquatic Invertebrates	5.1	LOEC in a 28-day *Daphnia magna* lifecycle test. Note that in a data review by BC MOE, a LOEC of 0.0093 mg/L and NOEC of 5.1 µg/L were identified from this study.	[125]
	Benthic Invertebrates	32.6	Reduced growth of mayfly (*Ephemerella mucronata*) from a four week exposure period.	[130]
	Aquatic Vegetation	270	Twenty-one day EC_{50} divided by an uncertainty factor of 2 to provide a LOEC for *Pediastrum tetras.*	[131]
Copper	Aquatic Invertebrates	2.83	Cladoceran (*Daphnia pulex*) EC_{20} for survival based on a water hardness of 57.5 mg/L. The EC_{20} is 9.16 µg/L at a hardness of 230 mg/L.	[132]
	Benthic Invertebrates	6.1	LCV for *Gammarus pseudolimnaeus*	[125]
	Aquatic Vegetation	15.75	Green alga (*Chlamydomonas reinhardtii*) 10-day EC_{50} divided by an uncertainty factor of 2.	[132]
Iron	Aquatic Invertebrates	4,380	*Daphnia magna* reproductive impairment in 16% of the test species (EC_{16})	[125]
	Benthic Invertebrates	4060	Aquatic sowbug (*Asellus aquaticus*) 48-hr LC_{50} of 81100 µg/L/20.	[133]
	Aquatic Vegetation	1,900	Duckweed (*Leman minor*) growth EC_{50} of 3700 µg/L/2.	[133]
Phosphorus	Aquatic plants, invertebrates,	See		[127]

Parameter	Receptor	TRV (µg/L)	Endpoint	Reference
	and fish	discussion		
Selenium	Aquatic plants, invertebrates, and fish	2	BC MOE Guideline	[126]
Sodium	Aquatic Invertebrates	680,000	*Daphnia magna* reproductive impairment in 16% of the test species (EC_{16}).	[125]
	Benthic Invertebrates	121,000	Chloride toxicity benchmark used as a substitute.	[65] [128]
	Aquatic Vegetation	1,171,000	Chloride toxicity benchmark used as a substitute.	[65] [128]
Strontium	Aquatic Invertebrates	11,160	*Ceriodaphnia dubia* reproduction IC20	[134]
	Benthic Invertebrates	30,240	*Hyallella azteca* growth IC10	[134]
	Aquatic Vegetation	36,000	Green algae growth IC10	[134]
Zinc	Aquatic Invertebrates	47	LCV for *Daphnia magna*	[125]
	Benthic Invertebrates	5,240	LCV for caddisfly, *Clistoronia magnifica*	[125]
	Aquatic Vegetation	30	LCV for *Selenastrum capricornutum*	[125]

Table 4-41: Surface Water TRVs for Fish

Parameter	TRV (µg/L)	Endpoint	Reference
Chloride	598,000	Fathead minnow 33-day LC_{10}	[98]
Aluminum	75	Brown trout (*Salmo trutta*) LOEC of 150 µg/L and goldfish (*Carrassium auratus*) EC_{50} divided by an uncertainty factor of 2.	[120]
Cobalt	118	Chronic LC_{50} divided by an uncertainty factor of 4 to provide a LOEC for rainbow trout (*Oncorhynchus mykiss*). Fathead minnow has a 28-d MATC of 290 µg/L.	[135]
Copper	5.92	Chinook salmon EC_{20}. Value considered conservative based on low water hardness of test.	[132]
Iron	1,000	Ambient water quality guideline which incorporates fish toxicity data.	[133]
Phosphorus	See discussion		[127]
Selenium	2	BC MOE Guideline	[126]
Sodium	598,000	Chloride toxicity benchmark used as a substitute.	[65] [128]
Strontium	17,420	Fathead minnow growth IC_{20}. An LC_{10} of 67,000 was identified for the rainbow trout.	[134]
Zinc	35	LCV for Flagfish	[125]

Table 4-42: Surface Water TRVs for Herpetofauna

Parameter	TRV (µg/L)	TRV for SAR (µg/L)	Endpoint	Reference
Chloride	3,431,000	3,431,000	Northern Leopard Frog 108-day MATC	[98]
Aluminum	75 (clay free)	75 (clay free)	PWQO, same as fish.	[89]
Cobalt	12.5	0.9	Seven-day LC_{50} divided by an uncertainty factor of 4 for the narrowmouth toad (*Gastrophryne carolinensis*) and TRV for SAR based on LC1 in the same study.	[135]
Copper	190	190	Northern leopard frog (*Lithobates pipiens*) 7-day no effect concentration. An LC_{50} of 670 µg/L was identified.	[136]
Iron	1,000	1,000	Ambient water quality guideline.	[133]
Phosphorus	See discussion	See discussion		[127]
Selenium	2	2	BC MOE Guideline	[126]
Sodium	3,431,000	3,431,000	Chloride toxicity benchmark used as a substitute.	[65] [128]
Strontium	10,700	10,700	Chronic effects benchmark	[134]
Zinc	408	NV	LCV for the Cope's gray treefrog	[76]

4.3.4.3 Sediment

Sediment Toxicological Benchmarks

The screening identified the following COPCs as requiring further evaluation in the Tier 2 Assessment: arsenic, copper, manganese, molybdenum, silver, sodium, strontium, tungsten and zinc. The TRVs are summarized in Table 4-43. For manganese, the background concentration of 732 mg/kg (Table 4-21) was used as a TRV. For arsenic, the CCME PEL of 17 mg/kg was chosen as an appropriate TRV (Table 4-21). For molybdenum, the alternative guideline of 25 mg/kg (see Table 4-21) was used as a TRV. The identification of TRVs for all other COPCs in sediment is discussed below.

Table 4-43: TRV for Tier 2 Assessment

Parameter	TRV for Tier 2 Assessment (mg/kg)
Arsenic	17
Copper	149
Manganese	732
Molybdenum	25
Silver	1.7
Sodium	4000
Strontium	1781
Tungsten	960
Zinc	459

The following sources were reviewed for the purpose of selecting the sediment TRVs:

- Ontario Ministry of the Environment and Energy (MOEE) LEL and SEL [137];
- CCME ISQG and a PEL [88];
- Canadian Nuclear Safety Commission LEL and SEL for copper [138];
- US EPA Assessment and Remediation of Contaminated Sediments Program (ARCS) No Effect Concentration (NEC), Threshold Effect Concentration (TEC), and Probable Effect Concentration (PEC) [139];
- Consensus-Based TEC and PEC [140];
- US EPA Region 3 Biological Technical Assistance Group (BTAG) Freshwater Sediment Screening Benchmark [141];
- US EPA Region 4 Freshwater Sediment Screening Benchmark [142];
- US EPA Region 5 Freshwater Sediment Screening Benchmark [143];

- US EPA Region 6 Freshwater Sediment Screening Benchmark [144];
- Washington Sediment Quality Value (SQV) [107]; and,
- Toxicity studies, where applicable.

The summary of the review is provided in Appendix E.

Given the number of benchmarks and guidelines available, selection of one as the most appropriate and most reliable to predict toxicity to benthic species at a site is difficult. Each benchmark may be developed using a different methodology, resulting in varying advantages, limitations, levels of acceptance, different extent of field validation, and differing degree of environmental applicability [145]. Selection of one benchmark over another is also complicated by uncertainties associated with the bioavailability of contaminants in sediments, the effects of co-varying chemicals and chemical mixtures, the ecological relevance of the guidelines, and correlative versus causal relations between chemistry and biological effects [140]. Therefore, recent evaluations have compiled multiple benchmarks into one to yield consensus-based benchmarks to increase the reliability, predictive ability, and level of confidence in using and applying the benchmarks ([140], [146], [147]). The consensus-based approach provides a weight of evidence for relating chemical concentrations to actual biological effects. MacDonald et al. [140] combines the effect-level concentrations from several guidelines that have origins in Canada and the US of similar narrative intent through averaging to yield consensus-based lower and upper effect values for contaminants of concern. MacDonald et al. [140] evaluated the consensus-based values for reliability in predicting toxicity in sediments by using matching sediment chemistry and toxicity data from field studies. The results of the evaluation generally showed that the consensus-based values for individual contaminants provide an accurate basis for predicting the presence or absence of toxicity. The Consensus-Based PEC from MacDonald et al. [140], representing the geometric mean of published SQGs from a variety of sources, including values used by the MOEE and CCME (Appendix E), is widely accepted as a reasonable maximum basis for predicting toxic effects to benthic organisms because the PEC is the concentration above which adverse effects are expected to occur more often than not.

A Consensus-Based PEC is available for copper and zinc and were selected as the most appropriate benchmark protective of benthic organisms. As such, the Consensus-Based PEC of 149 mg/kg for copper and 459 mg/kg for zinc were used in this assessment.

For additional context, it is noted that the copper Consensus-Based PEC of 149 mg/kg is about half way between the CNSC LEL of 22.2 mg/kg and the CNSC SEL of 269 mg/kg. A CNSC value is not available for zinc; however, the zinc Consensus-Based PEC of 459 mg/kg is about half way between the MOEE LEL of 120 mg/kg and MOEE SEL of 820 mg/kg.

A Consensus-Based PEC was not available for silver, sodium, strontium or tungsten. The TRVs values for these COPCs in sediment are discussed below.

A) Silver

Based on a review of available benchmarks, the Washington SQV of 1.7 mg/kg was selected as the benchmark protective of benthic organisms exposed to silver in sediment. It is a low effects concentration for freshwater sediments based on a chronic 28-day *Hyalella azteca* toxicity study for mortality. The value of 1.7 mg/kg is the Cleanup Screening Level (CSL) used to identify sediment cleanup sites in the State of Washington and is the maximum chemical concentration or biological effects level allowed as a sediment cleanup level for the State of Washington [148]. Note that other silver benchmarks that were identified are based on a marine environment and are not applicable to the WWMF. In addition, the Washington SQV of 1.7 mg/kg is based on an effects concentration, rather than management considerations.

B) Sodium

No sediment benchmarks protective of benthic organisms exposed to sodium were found in the scientific literature for use in the evaluation. In the absence of data on toxic effects to benthic organisms exposed to sodium in sediment, soil effects concentrations for sodium were included. A LOAEL concentration of 4,000 mg/kg for earthworms was selected as the most appropriate benchmark protective of benthic organisms for sodium in sediment. The LOAEL is the lowest concentration at which a relevant adverse effect is demonstrated.

C) Strontium

The availability of sediment benchmarks for strontium protective of benthic organisms is limited. A predicted no effects concentration (PNEC) in sediment, developed for strontium was used as the strontium TRV. The strontium PNEC was derived from whole-sediment toxicity tests on benthic organisms and application of an assessment factor. The magnitude of the assessment factor (with a maximum of 100 for sediment PNEC values) is based on the confidence of the extrapolation from laboratory toxicity tests to ecosystem effects (i.e., acute/chronic exposures, number of taxonomic groups, number of trophic levels) – the lower the assessment factor the higher the confidence in the extrapolation [149]. A lower assessment factor would be applied to chronic tests on multiple species representing multiple trophic levels. Results from chronic tests with sublethal endpoints, such as reproduction, growth, emergence, sediment avoidance and burrowing activity, are considered most relevant due to the generally long term exposure of benthic organisms to sediment-bound substances [149]. The PNEC for sediment is derived by dividing the lowest available NOEC or a low effect concentration for 10 percent of the population (EC_{10}, a low effect percentile for 10 percent of the population) obtained in long-term tests by the appropriate assessment factor [149]. The PNEC for strontium was developed using an assessment factor of 1, indicating high confidence in its derivation. The strontium PNEC derived using this method is 1,781 mg/kg for freshwater sediment [150].

D) Tungsten

The availability of sediment benchmarks for tungsten protective of benthic organisms is limited. No directly measured sediment benchmarks protective of benthic organisms exposed to tungsten were found in the scientific literature. However, a PNEC for tungsten in sediment was developed by the European Chemicals Agency using the equilibrium partitioning method. This method uses a PNEC for aquatic organisms in water and applies a sediment/water partition coefficient to determine an equivalent value in sediment (i.e., the PNEC) [149]. The strontium PNEC for aquatic organisms in water was derived from the lowest available $NOEC/EC_{10}$ for growth or reproduction obtained from chronic toxicity tests with at least three species (i.e., normally fish, *Daphnia* and algae) representing three different trophic levels and taxonomic groups [149]. Primary producers (plants) are represented by algae; plant-eating animals are represented by invertebrates (e.g., *Daphnia*) and predators are represented by fish [149]. The PNEC for aquatic organisms was divided by an assessment factor of 10, indicating relatively high confidence in its derivation as the assessment factors applied to water PNEC values can range up to 1,000. This PNEC for aquatic organisms in water was then applied to the sediment/water partitioning coefficient to determine the sediment PNEC.

The tungsten PNEC derived using this method is 960 mg/kg for freshwater sediment [151]. There is some uncertainty associated with the extrapolation of a water PNEC to a sediment PNEC using partitioning coefficients. The European Chemicals Agency [149] recommends use of this approach as a preliminary screening to decide whether sediment toxicity tests with benthic organisms are required. The tungsten PNEC of 960 mg/kg was used in this assessment.

Evaluation of Benthic Invertebrate Field Data

Benthic invertebrate community samples were collected as part of aquatic environment baseline field studies in 2014. As a line of evidence in the overall risk evaluation, a qualitative assessment of the benthic invertebrate field data was completed to evaluate the potential impairment of the benthic invertebrate community. Changes in sediment quality generally result in changes in the types, numbers, or diversity of the benthic community. In general, a sediment "impairment" exists if a body of water does not support its designated uses (drainage ditches and settling ponds) or has exceedances of toxicity based values. To determine if impairment has occurred, the benthic community structure in the waterbody of interest is compared to that in a reference site. Reference sites were not identified for the water bodies on the WWMF. Therefore, impairment was assessed using a gradient approach starting with the west end of the SRD and examining benthic community structure and sediment quality between the upstream location (SRD-1) in the SRD and the downstream location (SRD-4). However, there were limitations in the use of this approach, based on the resulting geographical distribution of the biological and chemistry data.

Benthic macroinvertebrate species have different tolerances to biotic and chemical factors in their environments [152]. Consequently, community structure has commonly been used as an indicator of the condition (or health) of aquatic systems [152]. Biotic indices have been developed to quantify effects of environmental conditions and pollutants on specific organisms and community function. Changes in presence/absence, density, morphology and diversity can indicate that chemical conditions are causing biological effects. Presence of numerous families of organic pollution tolerant species can indicate the presence of chemical stressors or anoxic conditions in sediment.

Sample locations were selected so as to provide a representative survey of biota and habitat types within the study reaches of the water features that were indicative of baseline conditions and to provide comparability on past sampling programs. Aquatic habitat and fish community surveys were conducted concurrently with surface water and sediment baseline sampling when applicable. Details concerning taxonomic identification, the benthic invertebrate metrics, and habitat characteristics of the water features are provided in Appendix E. Additional information on the calculation of the indices, as applicable, is also provided in Appendix E. In brief, the indices include:

1. Total benthic invertebrate abundance/density – indicates the number of invertebrates identified within a sample where, interpretation is based on comparison to other sample locations, preferably a reference location or using a gradient of exposure (high to low);
2. Family richness – number of benthic families identified in a sample; where, interpretation is based on comparison to other sample locations, preferably a reference location or using a gradient of exposure (high to low);
3. Simpson's evenness, otherwise referred to as Evenness Index –a measure of the relative abundance of the different species making up the richness of an area. The value of this index ranges between 0 and almost 1; where, the greater the value, the less variation in communities between the species (1 = equal proportions of all species);
4. Simpson's index of diversity – abundance pattern and taxonomic richness; range is from 0 to 1 where a value of 1 has the highest diversity;
5. Percent EPT and percent chironomids – supporting descriptors of the benthic invertebrate communities sampled where EPT are sensitive invertebrates and chironomids are tolerant invertebrates;
6. Fraction of taxa – field data used to calculate Hilsenhoff Biotic Index (HBI);
7. HBI - summarizes benthic communities in stream environments based on known tolerances of organisms to organic pollution and anoxic environments;
8. Feeding habits – aids in interpretation of biological effects at the ecosystem scale; and,
9. Tolerance – a value specific to the benthic family as provided by Hilsenhoff, 1988 and is used in the calculation of the HBI. Tolerance values from: 0 to 2 indicate sensitivity to organic pollution; from 4 to 6 indicate moderately sensitive to organic pollution; and, 8 to 10 indicate tolerant of organic pollution.

Benthic invertebrate communities at each sample location were characterized using a series of descriptors, as provided in Table 4-44 and Table 4-45, and described below.

Table 4-44: Tolerance and Feeding Habits for the Benthic Macroinvertebrates Collected during Monitoring

Taxa List	Taxa Characteristic		Fraction of Taxa at Sampling Location				
	Tolerance	Feeding habit	SRD-1	SRD-4	WD-4	GS-1	WTL-1
ANNELIDA:HIRUDINEA:							
ERPOBDELLIDAE:	3	predator				0.0146	
GLOSSIPHONIIDAE:	8	parasite/predator	0.0068				
ANNELIDA:OLIGOCHAETA:							
LUMBRICIDAE:	6	collector-gatherer			0.0052	0.0351	0.0033
LUMBRICULIDAE:	5	collector-gatherer					0.0131
NAIDIDAE:	6	collector-gatherer					0.0033
TUBIFICIDAE:	10	collector-gatherer	0.0822	0.082		0.8158	0.0033
CRUSTACEA:AMPHIPODA:							
CRANGONYCTIDAE:	6	collector-gatherer			0.0131		0.0098
GAMMARIDAE:	4	collector-gatherer	0.0068		0.0783		
CRUSTACEA:ISOPODA:							
ASELLIDAE:	8	collector-gatherer	0.0822	0.6148	0.6475		0.2908
INSECTA:							
COLEOPTERA:							
ELMIDAE:	4	collector-gatherer		0.1557	0.0679		
HALIPLIDAE:	5	shredder	0.0068			0.0029	
DIPTERA:							
CERATOPOGONIDAE:	6	predator			0.0052	0.0058	
CHIRONOMIDAE	8	collector-gatherer	0.6781	0.082	0.0052	0.0263	0.0392
SIMULIIDAE:	6	filter feeder			0.0078		0.0033

Taxa List	Taxa Characteristic		Fraction of Taxa at Sampling Location				
	Tolerance	Feeding habit	SRD-1	SRD-4	WD-4	GS-1	WTL-1
TABANIDAE:	6	predator		0.0164		0.0058	
TIPULIDAE:	3	herbivore/predator		0.0082	0.0026		0.0033
LEPIDOPTERA:							
CRAMBIDAE (=PYRALIDAE)	5	shredder			0.0078		
ODONATA:							
AESHNIDAE:	3	predator			0.0026	0.0029	
MOLLUSCA:BIVALVIA:							
SPHAERIIDAE:	8	filter feeder	0.1164	0.041	0.1123	0.0029	0.402
MOLLUSCA:GASTROPODA:							
LYMNAEIDAE:	6	scraper				0.0117	
PHYSIDAE:	8	scraper				0.0029	
PLANORBIDAE:	7	scraper	0.0205			0.0731	0.2288
NEMATODA:					0.0026		
PLATYHELMINTHES:							
PLANARIIDAE:	1	omnivore			0.0418		
TOTAL			**1**	**1**	**1**	**1**	**1**
HBI			8.09	7.47	6.99	9.34	7.68

Note: HBI 0-5 indicates good water quality and organic pollution is unlikely; a HBI score between 5 and 6 is classified as fairly substantial organic pollution likely; HBI score between 6 and 7 is classified as very substantial organic pollution likely; and HBI score greater than 7 as severe organic pollution likely.

Table 4-45: Benthic Community Indices for the WWMF Baseline Study

Drainage Feature	**South Railway Ditch**		**Wetland**	**Grassed Swale**	**West Ditch**
Sampling Location	**SRD-1**	**SRD-4**	**WTL-1**	**GS-1**	**WD-4**
Total Invertebrate Abundance	146	244	612	684	766
Total Invertebrate Density (#/m^2)	2,116	3,536	8,870	9,913	11,101
Family Richness	8	7	11	12	14
Simpson's Diversity Index	0.51	0.5	0.70	0.33	0.56
Evenness Index	0.26	0.3	0.30	0.12	0.16
Percent EPT	0	0	0	0	0
Percent Chironomids	67.8	8.2	3.92	2.63	0.52

A) South Railway Ditch

Constructed during the initial development of the Bruce Nuclear Generating Station in the 1960s, the SRD is approximately 1.8 km in length (Figure 4-4). The SRD begins west of the WWMF, near the Sewage Processing Plant, and flows eastwardly along the northern margin of the WWMF and adjacent to an abandoned railway bed (Siding Road). In the area of SRD-3 the water turns and moves south. There is no longer a defined channel and water disperses along the easterly side of the Wetland. In this area there is a connection between the SRD and Wetland (i.e., WTL-1). Water from the SRD and Wetland then flows through a culvert under Siding Road. On the other side of the road, the SRD flows through another culvert to the northeast and eventually drains into Stream C. The SRD collects surface water runoff from the WWMF, in addition to groundwater discharge. The SRD has become colonized by aquatic plants, predominantly cattails, invertebrates and a limited number of small bodied fish.

During the 2014 sampling campaign, all locations in the SRD were classified as pools (or flats: shallow pools). Substrates within the ditch were found to be dominated by fines (silt and clay) in upstream sections (SRD-1 to SRD-4). Wetted widths and depth were variable with respect to the season that surveys occurred and the site where sampling took place. Over the course of the 2014 open water period they generally ranged from 2.2 to 2.5 m in wetted width and 0.17 to 0.25 m in depth. Overall, the families present within the ditch are considered moderately to highly tolerant to low oxygen conditions that occur during periods of low flow due to decay of plant material.

- Sampling location SRD-1

  The gravel Siding Road is close to sample location SRD-1 (~ 5 m). The close proximity to the roadway limits the riparian vegetation available to buffer land-use impacts of the gravel roadway at the right bank (i.e., to the north) of the watercourse. Conversely, the land use adjacent to the left bank (i.e., to the south) of SRD-1 was open grassland with a building within 100 m of the watercourse.

  Benthic macroinvertebrate samples were collected in a low gradient pool/flat, with hydraulic head measurements falling between 0 and 3 millimeters (mm). Despite containing riparian vegetation in the form of small trees and low lying shrubs, ferns and grasses, the watercourse at SRD-1 had high light/solar penetration because the overhead canopy had low coverage (i.e. open canopy site). Substrate composition along this section of the SRD was predominately made of soft material, providing little stream-bed stability, as it was primarily composed of fines (particles <2 mm), with small amounts of gravel (particles between 2-100 mm) and cobble (particles between 100-1000 mm). Little instream woody debris was present within SRD-1; however, dense cattail growth was found choking the majority of the channel, representing the only available instream cover. The soft fine substrate will be subjected to scour and re-suspension during runoff events, which may impact the benthic community by washing specimens downstream. Dense stands of cattails occupy most of the channel. The cattails will provide some protection against the scouring effects of high discharge events during the growing season. However, during periods of die-back in the autumn and early spring, cattails will provide little protection during high discharge events and scouring of bottom sediments may occur.

This SRD-1 sampling location had the lowest benthic macroinvertebrate density of all the sampling locations. The family richness or diversity at this location was the second lowest of all sample locations. Simpson's index of diversity, evenness, and organic pollution tolerance at this location are dominated by a single family – chironomids, which were approximately 67 percent of the macroinvertebrates observed at the sample location. Chironomids are often associated with degraded or low biodiversity ecosystems because some species have adapted to virtually anoxic conditions and are dominant in polluted waters [153]. The HBI of 8.09 indicates that the habitat quality is very poor. An abundance of decaying organic matter in the form of plant debris may lead to low oxygen concentrations in surface water during periods of stagnation and anoxic conditions in bottom sediments. The remainder of the benthic macroinvertebrates had representation of the major feeding guilds (scavengers, collector-filter feeders, collector-gatherers and parasites). The two most represented feeding guilds are predators and collector-gatherers, which indicates that there is a large source of fine particulate organic matter (FPOM) on the channel bed.

The data suggest some level of impairment of the benthic community. It is difficult to differentiate between the effects of poor habitat and/or metal contamination within the SRD. The impaired communities could be caused by anoxic conditions (which could be associated with organic loadings from plant debris or from stagnant water) elevated concentrations of COPCs in sediment, or other biological and habitat characteristics.

- Sampling location SRD-4

This area of the SRD has intermittent flow with periods of no flow occurring especially in late summer and early autumn. Ditching is present to allow water levels to extend south to the culvert that connects the WTL-1 sampling station to SRD-4 during periods of elevated water levels. The sampling location was situated in a small section of ditching east of Siding Road and south of a small access road to an industrial service station, approximately 1 kilometer (km) down gradient of SRD-1. The observed wetted area at SRD-4 was roughly 15 square meters (m^2).

Benthic macroinvertebrate samples were collected in a low gradient pool/flat, with hydraulic head measurements falling between 0 and 3 mm. The riparian zone surrounding the SRD-4 sampling station was composed of exposed gravel and rock, small trees and low lying shrubs, ferns and grasses. Light/solar penetration was high at this sample location because of an open vegetative canopy.

While flows into SRD-4 (as monitored by the upstream WTL-1 sensor station) were found to be continuous in the spring, dry events were detected during periods of the summer. Extended dry periods at WTL-1 without discharge into SRD-4 indicate this section of the SRD has intermittent flow, influenced by seasonal fluctuations and precipitation events. However, SRD-4 was found to be continuously wetted. Channel substrate exhibited low heterogeneity and low stream-bed stability which was composed exclusively of fines (particles <2 mm). Low instream wood debris was present at SRD-4 and dense cattail growth was found in this section of channel, providing the majority of instream cover.

The SRD-4 sampling location had higher macroinvertebrate density compared to SRD-1. However, the family richness and diversity at this location was the lowest of all sample locations. Simpson's index of diversity, evenness, and the organic pollution tolerance index indicate that a single family – Asellidae (isopods) dominates this monitoring location. Asellidae feed on dead animal and plant matter; thus, the abundance of this family will increase in eutrophic conditions. Isopods composed approximately 62 percent of the macroinvertebrates observed at the sample location. However, the presence of Elmidae (riffle beetles) usually indicates water quality is good with fewer pollutant stressors ([153], [154]). The remainder of the benthic macroinvertebrate species represented the major feeding guilds (collector-filter feeders, collector-gatherers and predators). The dominant feeding guild at this sample location is the collector-gatherers, which indicates a source of FPOM in the SRD. Other feeding guilds are present in small and similar proportions. The HBI of 7.47 indicates that the habitat quality is very poor and that severe organic loading from plant debris and anoxic conditions are likely.

The benthic macroinvertebrate community structure within the SRD is characteristic of a stressed habitat. It is difficult to assess whether the limited benthic macroinvertebrate community consisting primarily of tolerant and facultative species is strictly the product of the poor quality habitat or whether elevated sediment concentrations of COPCs are having an effect.

B) Wetland

Located on the east side of the WWMF study area, the Wetland covers approximately 4 ha. The Wetland is largely boarded by Siding Road to the east and Central Services Road to the south. Along the west side of the Wetland was a former Grassed Swale which has been reconstructed into a storm water management system which includes two settling ponds and a polishing pond. When flow is sufficient, water will flow from the polishing pond over rock rubble into the Wetland. This is in the area of sample location GS-1. The Wetland receives drainage from three sources on site which includes the South Railway Ditch, the Grassed Swale and the Construction Landfill 1. More appreciative flows originate from the SRD which continues along the northeastern and eastern margins of the Wetland before passing under Siding Road on its path to Stream "C". 2014 surveys found that the Wetland receives a reduced proportion of surface water from the Grassed Swale then previously reported. As a result of Grassed Swale re-configuration, fluctuations in water levels in the Wetland were largely attributed to precipitation events, which would include surface water from the polishing pond once water levels exceeded holding capacity. While surveys did not find evidence to support the presence of groundwater inputs, the isolated nature of the Wetland suggests there is groundwater recharge potential within this water feature. The Wetland was found to be dominated by dense cattail stands, sparsely intermixed with areas of standing water. Surveys in 2014 found that the Wetland is slowing taking on a meadow marsh hydrological regime as few areas of standing water were located. Substrate within the Wetland was made of organic matter (decaying vegetation) (95%) and fines (silts and clay) (5%).

- Sampling location GS-1

During 2013 and 2014 the Grassed Swale was modified to provide an increase in capacity for storm water management and reduce suspended sediment loading and deposition in the downstream environment. The modifications included an overall increase in the size of the Swale and the introduction of permanent pools to provide water quality treatment. The benthic macroinvertebrate sampling was carried out in a shallow gradient pool/flat, with hydraulic head measurements falling between 0 and 3 mm. The riparian vegetation had grasses, sedges, shrubs, trees and ferns. The GS-1 sample location in the Wetland, just downstream of the stormwater management system (i.e., former Grassed Swale), provides some protection from light/solar penetration as the existing vegetation provided a moderately closed canopy. Substrate composition at GS-1 was composed of predominately fines, with small amounts of gravel.

The macroinvertebrate density and family richness were greater at the GS-1 sampling location than sample locations in the SRD. Simpson's index of diversity and evenness were the lowest of the sample locations. A single family, Tubificidae, was found in higher proportion than other macroinvertebrates at this sample location. Tubificidae composed 82 percent of the benthic community at this sample location. Tubificid worms have long been recognized as organic pollution-tolerant because of their ability to thrive under poor water quality conditions. Their blood contains hemoglobin, which enables them to survive in waters where oxygen is lacking [155]. The high proportion of tubificid could be caused by the recent modification to benthic habitat. However, low numbers of two families of relatively sensitive macroinvertebrates - Erpobdellidae (1 percent) and Aeshnidae (0.3 percent) were present. The trophic structure of the benthic community also indicates that most of the macroinvertebrates are collector-gatherers which indicates the presence of an abundance of fine particulate material. The HBI of 9.34 indicates that the habitat quality is very poor. An abundance of decaying organic matter in the form of plant debris may lead to low oxygen concentrations in surface water during periods of stagnation and anoxic conditions in bottom sediments.

The benthic community at GS-1 has a limited fauna of mainly tolerant organisms that tolerate low oxygen concentrations and high levels of decaying plant debris. The benthic macroinvertebrate community composition is likely associated with habitat disturbances in association with construction (i.e., 2013, 2014) in addition to the presence of low flows and stagnant water, leading to low oxygen concentrations.

- Sampling location WTL-1

Sampling location WTL-1 is located at the outflow from the Wetland in the pool of water in the SRD at the upstream side of the culvert under Siding Road. Ditching allows water to extend to the corrugated steel culvert and flow to SRD-4 during periods of elevated flows. The Wetland consisted of dense cattail stands with sparsely intermixed areas of standing water. A defined channel could be identified and benthic macroinvertebrate sampling at WTL-1 took place in a wetted area with dense cattail cover. The substrate composition of this area was predominately cattail root masses with small amounts of fines. Surveys in 2014 found that the Wetland is slowly taking on a meadow marsh hydrological regime as few areas of standing water were located.

The macroinvertebrate density and family richness were greater at this sample location compared to sample locations in the SRD and several organic pollution tolerant families had high proportions: Asellidae (29 percent), Sphaeriidae (40 percent), and Planorbidae (23 percent). Simpson's index of diversity was highest at this location compared to all other sample locations. Evenness was similar to the other locations in the SRD. However, a HBI of 7.68 indicates that the habitat quality is very poor. As at other sampling locations, the presence of an abundance of decaying organic matter in the form of plant debris may lead to low oxygen concentrations in surface water during periods of stagnation and anoxic conditions in bottom sediments. The trophic structure at WTL-1 is predominantly collector-gatherers, predators, filter feeders, and scavengers and the important feeding guilds for a food web are present. The high proportion of collector-gatherers indicates that there is a source of FPOM in the Wetland. Other feeding guilds are present in small and similar proportions.

The benthic community with the Wetland is limited t to mainly tolerant organisms, as may be anticipated in association with a habitat with low oxygen and intermittent wet conditions.

C) West Ditch (sampling location WD-4)

The West Ditch (WD) is an industrial drainage ditch that was constructed in the 1960s with development of OPGs Bruce Power site. The WD originates at the western edge of the project area and flows westerly to Lake Huron. The WD receives drainage from a large area including the lay-down area (part of WWMF expansion) and Bruce Power leased lands. Both east and west branches of WD convey water from the OPG lay-down area. The WD has become colonized by aquatic plants, invertebrates and a limited number of small bodied fish and white sucker.

The benthic macroinvertebrate samples were collected in a shallow glide, with hydraulic head measurements ranging between 4 and 7 mm. Substrate composition along this section of the WD was composed of predominately cobble (particles between 100 – 1000 mm), with smaller amount of gravel and fines. This section of the WD watercourse channel is excavated bedrock, with both right and left banks being nearly vertical cut banks. Overhanging trees within the WD-4 riparian zone provided dense instream canopy coverage which had minimal light/solar penetration. Cattail and watercress was observed in low densities.

Benthic macroinvertebrate sampling at WD-4 was performed immediately downstream of a storm water inlet with heavy boulder armouring. This sample location had the highest macroinvertebrate density and family richness compared to other sample locations. Simpson's index of diversity and evenness indicate that a single family

(Asellidae) was found in higher proportions than other macroinvertebrates at this sample location. Two organic pollution tolerant families composed a large proportion of the benthic communities, Asellidae (65 percent) and Sphaeriidae (11 percent). The HBI of 6.99 indicates that the habitat quality is very poor. However, based on tolerance values, one moderately sensitive benthic family, Gammaridae, (7 percent) and one sensitive benthic family, Planariidae, (4 percent) were also part of the benthic community at this sample location. The remainder of the benthic macroinvertebrates represented the major feeding guilds (collector-filter feeders, collector-gatherers and predators). The dominant feeding guild at the West Ditch was the collector-gatherers, indicating that there is a source of FPOM in the West Ditch. Other feeding guilds are present in small and similar proportions.

The benthic macroinvertebrate community structure is reflective of a stressed habitat such as that of an industrial drainage ditch. It is difficult to assess whether the community, which consists primarily of tolerant species, is the result of poor quality habitat or if elevated sediment concentrations are having an effect.

D) Summary

Sensitive species such as mayflies (Ephemeroptera), caddis flies (Trichoptera) and stoneflies (Plecoptera) were absent from the benthic community at the WWMF. The SRD does not specifically provide typical habitat (i.e. larger particle substrates, higher velocities and high oxygen) for these aquatic insect orders (EPT) and their absence from the benthic community is expected. The habitat associated with the SRD is depositional nature, and it is expected that families associated with depositional environments (e.g., chironomids, gastropods) would be found in the greatest abundance.

The total number of invertebrates was low in SRD at both SRD-1 and SRD-4 with chironomid larvae (*Chironomus*) dominant in the benthic community at SRD-1 and isopods (*Caecidotea*) at SRD-4. Invertebrate numbers were higher in the Wetland (GS-1) and WTL-1 located at the outflow of the Wetland by a factor of 3-5 compared to the SRD-1 and SRD-4. Despite GS-1 and WTL-1 having nearly an equivalent number of specimens and both being associated with the Wetland, there were substantial differences in benthic community structure. At GS-1 tubificid worms and snails (*Gyraulus circumstriatus*) were dominant, whereas at WTL-1 isopods (*Caecidotea sp.*), finger nail clams (*Pisidium sp.*) and snails (*Gyraulus circumstriatus*) were dominant (Appendix E).

The highest number of benthic invertebrates was found in the WD at location WD-4. High numbers at WD-4 probably reflect both the stable substrate of bedrock and rock armouring and the permanent presence of slow-flowing water. The more favorable habitat at WD-4 is evident in the benthic community composition with gammarids (*Gammarus fasciatus*), isopods (*Caecidotea sp.*), elmid beetles (*Dubiraphia quadrinotata* and *Optioservus fastiditus*) and finger nail clams (*Pisidium sp*.) dominant in the benthic community. Isopods, although most abundant at WD-4, were also abundant at WTL-1 and SRD-4 and were present at SRD-1. Most amphipods (*Crangonyx* and *Gammarus*) were collected at WD-4. The rock armouring at WD-4 may have provided ideal habitat for them.

Family richness and species richness were low in the drainage ditches and Wetland compared to most southern Ontario streams, varying from 7 to 14 families and 11 to 17 species. Lower values were found in the SRD, whereas higher values were found at GS-1 and WD-4. In agreement with this, diversity as measured by the Simpson's Diversity Index was relatively low, about 0.5 at SRD-1, SRD-4 and WD-4. Diversity was highest at WTL-1 (0.70) and lowest at GS-1 (0.33), the two sampling locations in the Wetland. Taxa evenness was low at all sampling locations with SRD-1, SRD-4 and WTL-1 being approximately equivalent (~0.3) and GS-1 (0.12) and WD-4 (0.16) being very low. Chironomids formed a large component of the fauna at SRD-1 (67.8%), but only a small portion of the benthic community at the other four locations (0.52-8.2%). Based on the benthic invertebrate community present at each sampling location, the Hilsenhoff Biotic Indices indicate poor to very poor water/sediment quality. Therefore, the industrial drainage ditches and Wetland on the WWMF provide poor quality habitat to support benthic invertebrates. Most of the benthic invertebrate species collected are organic pollution tolerant species that can tolerate low oxygen conditions experienced in the drainage ditches and Wetland. The relative abundance of the Central Mudminnow (*Umbra limi*) within the SRD system (including the Grassed Swale and Wetland) may further demonstrates the potential for anoxic conditions there as this species is known to have the ability to survive during periods of stagnation through gulping air from the surface into a specialized swim bladder.

Dissolved oxygen (DO) concentrations were measured in surface water at each location in April, July and October, 2014. In April, DO concentrations were high which possibly reflects the high levels of oxygen in runoff waters and low levels of organic plant decay in spring to consume oxygen. Dissolved oxygen concentrations were low in summer and in autumn (i.e., 1.77 mg/L at SRD-1 and 3.44 mg/L at SRD-4 in July and 4.44 mg/L at SRD-1 and 5.32 mg/L at SRD-4 in October). The water quality guideline for DO in warm water for protection of aquatic life is 5.5 mg/L [88]. Sensitive aquatic insects may show effects at concentrations below 5.5 mg/L.

Under oxic conditions metals may be lost from the water to sediment with binding to various ligands such as metal oxides (iron oxides and manganese oxides), organic matter, and carbonates greatly reducing their availability to biota [193]. During periods of low flow or no flow (stagnation) near anoxic conditions may develop in the water column and under reducing conditions in the sediment redox sensitive metals (iron and magnesium and co-precipitated metals) may be released from sediment to the porewater and diffuse back into the water column or bind strongly to other ligands in the sediment such as organic matter and sulphide [193]. The net effect being an overall reduction in the availability of the metals for uptake by biota.

4.3.4.4 Birds and Mammals

TRVs used in the evaluation of risks to both terrestrial and aquatic birds and mammals are based on an acceptable exposure dose (in mg/kg/day) as opposed to medium concentration. TRVs for birds and mammals are developed through the use of toxicity studies that commonly assess growth, reproduction, and mortality. The benchmarks commonly employed are the NOAEL for protection of individual receptors such as SARs, and the LOAEL for population effects.

TRVs and toxic endpoints for the assessment of the terrestrial receptors are summarized in Table 4-46, and for aquatic birds and mammals are summarized in Table 4-47.

For the TRVs for Aquatic Birds and Mammals, it should be noted that the ability to quantitatively assess potential risks with sodium and chloride is complicated by the lack of suitable TRVs and uncertainty in exposure through the food chain. Sodium and chloride are essential for animals and are not commonly considered to cause toxicity. However, under certain conditions, adverse impacts may occur and therefore further evaluation is provided for the aquatic birds and mammal (i.e., mallard, bald eagle and the muskrat).

Sodium and chloride have been identified separately as COPCs in surface water. Estimated concentrations of sodium chloride are 709 mg/L, based on sodium being the limiting factor in the formation of sodium chloride.

Table 4-46: TRVs and Toxicity Endpoints for Terrestrial Birds and Mammals

COPC	Receptor	TRV (mg/kg/d)	Endpoint	Reference
Dioxins and Furans	Mammals	0.00001	Reproduction (LOAEL)	[122]
	Mammals (SAR)	0.000001	Reproduction (NOAEL)	[122]
	Birds	0.00014	Reproduction (LOAEL)	[65]
	Birds (SAR)	0.000014	Reproduction (NOAEL)	[65]

Table 4-47: TRVs and Toxicity Endpoints for Aquatic Birds and Mammals

COPC	Mammal (mg/kg/day)	LOAEL Based Endpoint	Birds (mg/kg/day)	LOAEL Based Endpoint	Species at Risk (Birds) (mg/kg/day)	NOAEL Endpoint
Aluminum	19.3 (water); 100 (food/sediment)	Mouse Reproduction [122]	109.7	Ringed Dove NOAEL Reproduction [122]	109.7	Ringed Dove NOAEL Reproduction [122]
Arsenic	1.3	Mouse Reproduction [122]	7.4	Brown-headed cowbird Survival [122]	2.24	Chicken Growth, reproduction and survival [156]
Chloride	NV		NV		NV	
Cobalt	8.8	Rat Growth LOEL [65]	7.8	Chicken Growth LOEL [157]	7.61	Growth geometric mean of avian NOAELs [157]
Copper	15	Mink Reproduction [122]	15.7	Chicken Weight loss (growth) [158]	4.05	Chicken Reproduction [159]
Iron	544	Rat Growth LOAEL [160]	56	Chicken Growth [161]	25	Chicken Growth [161]
Manganese	284	Rat Reproduction [122]	977	Japanese Quail Growth NOAEL [122]	977	Japanese Quail Growth NOAEL [122]
Molybdenum	2.6	Mouse Reproduction [122]	35	Chicken Reproduction [122]	3.5	Chicken Reproduction [122]
Selenium	0.33	Rat Reproduction [122]	0.3	Chicken Reproduction [162]	0.2	Chicken Reproduction [162]

COPC	Mammal (mg/kg/day)	LOAEL Based Endpoint	Birds (mg/kg/day)	LOAEL Based Endpoint	Species at Risk (Birds) (mg/kg/day)	NOAEL Endpoint
Silver	60.2	Pig LOAEL [163]	20.2	Turkey Growth LOAEL [163]	2.02	Turkey Growth LOAEL divided by 10 [163]
Sodium	NV		NV		NV	
Strontium	633	Rat US EPA IRIS [164]	NV		NV	
Tungsten	NV		NV		NV	
Zinc	320	Rat Reproduction [122]	109	Mallard Survival [165]	66.1	Reproduction and growth geometric mean of avian NOAELs [166]

NV – No Value

4.3.4.5 Herpetofauna – Soil Exposure

Toxicity benchmarks associated with COPCs in the aquatic habitat are addressed in Section 4.3.4.2.

In the terrestrial habitat, the only COPC is dioxins and furans in soil. Dioxins and furans exert toxic effects through binding to the aryl hydrocarbon receptor. This common mechanism of action has led to dioxins and furans as being assessed through the use of TEQ. Amphibians and reptiles are relatively insensitive to dioxin-like substances. Data demonstrating dioxin-like effects are limited, and effects have been observed at relatively high concentrations [167]. A toxicity benchmark for herpetofauna could not be identified. Herpetofauna will be assessed qualitatively.

4.3.5 Risk Characterization

Risk will be quantified for each category based on the calculation of an HQ.

If the HQ for each non-radiological COPC is less than one, then no adverse effects are likely as concentrations are below levels that are known to cause potential adverse effects. If the HQ exceeds one, it may be inferred that potential adverse effects to individuals are possible. Inferences about potential effects can be made given a certain magnitude and type of effect associated with the assessment benchmark or endpoint. An HQ > 1 indicates that there is the potential for adverse effects and further assessment is required.

In general terms, an increase in exposure is associated with an increase in risk. As the magnitude of the HQ increases so does the potential for environmental effects, the likelihood of the effect depending on the magnitude of exposure and the endpoint used to assess effects.

The risk from non-radiological COPCs will only be calculated for those contaminants that were passed forward from the screening assessment performed in Section 4.3.2.6 and the exposure concentration and dose assessment performed in Section 4.3.3.

The HQ will be calculated for non-radiological COPCs as follows:

$$HQ = \frac{Exposure\ Value}{Benchmark\ Value}$$

Any of the calculated HQs that exceed one in the sections below will be emphasized in the risk estimation table by highlighting the cell and bolding the value.

For all receptors other than birds and mammals, a risk characterization is performed for each medium; the total risk due to a COPC from all applicable pathways is only calculated for birds and mammals [2].

4.3.5.1 Terrestrial Plants and Invertebrates

Based on the estimated soil exposure concentrations and effect levels presented in Sections 4.3.3.1 and 4.3.4.1, exposure ratios are provided in Table 4-48 for terrestrial plants and invertebrates.

Table 4-48: Risk Estimates to Terrestrial Plants and Soil Invertebrates

Soil COPC	Unit	Receptor	Exposure Concentration	Effect Concentration	HQ
Sodium Adsorption Ratio	µg/g	Non-SAR	3.7	12	0.31
		SAR	0.28	2.4	0.12
Dioxins and Furans	pg/g	Non-SAR	23.3	99	0.24
		SAR	4.3	7	0.61

In both the case of non-SAR and SAR plant receptors, the sodium adsorption ratio concentration is below the effect concentration. Therefore no risk from sodium adsorption ratio has been identified and no further analysis is required.

In both the case of non-SAR and SAR plant receptors, the dioxin and furan concentration is below the effect concentration. Therefore no risk from dioxins and furans to plants and invertebrates has been identified and no further analysis is required.

4.3.5.2 Aquatic Receptors-Risks due to Exposure to Surface Water

Based on the estimated surface water exposure concentrations and aquatic TRVs presented in Sections 4.3.4.1 and 4.3.4.1, exposure ratios are provided in Table 4-49 for aquatic plants and invertebrates, Table 4-50 for fish, and Table 4-51 for herpetofauna.

Table 4-49: Risk Estimates to Aquatic Plants and Invertebrates

Surface Water COPC	Exposure Concentration (µg/L)	TRV (µg/L)			HQ		
		Aquatic Plants and Algae	Aquatic Invertebrates	Benthic Invertebrates	Aquatic Plants and Algae	Aquatic Invertebrates	Benthic Invertebrates
Dissolved Chloride	460,000	1,171,000	421,000	121,000	0.4	**1.1**	**3.8**
Aluminum (clay-free)	24	230	320	416	0.1	0.1	0.1
Cobalt	1	270	5.1	32.6	0.004	0.2	0.03
Copper	5	15.75	2.83	6.1	0.3	**1.8**	0.8
Iron	1,440	1,900	4,380	4,060	0.8	0.3	0.4
Phosphorus	291.7	N/A	N/A	N/A	N/A	N/A	N/A
Selenium	2	2	2	2	**1.0**	**1.0**	**1.0**
Sodium	29,900	1,171,000	680,000	121,000	0.03	0.04	0.2
Strontium	3,570	36,000	11,160	30,240	0.1	0.3	0.1
Zinc	103.3	30	47	5,240	**3.4**	**2.2**	0.02

Table 4-50: Risk Estimates to Fish

Surface Water COPC	Exposure Concentration (µg/L)		TRV (µg/L)	HQ	
	On-Site Receptors	Lake Huron Receptors		On-Site Receptors	Lake Huron Receptors
Dissolved Chloride	460,000	420,000	598,000	0.8	0.70
Aluminum (clay-free)	24		75	0.3	
Cobalt	1		118	0.01	
Copper	5		5.92	0.8	
Iron	1,440		1,000	**1.4**	
Phosphorus	291.7		N/A	N/A	
Selenium	2		2	**1.0**	
Sodium	299,000	245,000	598,000	0.5	0.41
Strontium	3,570	2300	17,420	0.2	0.13
Zinc	103.3	24.1	35	**3.0**	0.69

Table 4-51: Risk Estimates to Herpetofauna

Surface Water COPC	Exposure Concentration (µg/L)	Non-SAR		SAR	
		TRV (µg/L)	HQ	TRV (µg/L)	HQ
Dissolved Chloride	460,000	3,431,000	0.13	3,431,000	0.13
Aluminum (clay-free)	24	75	0.32	75	0.32
Cobalt	1	12.5	0.08	0.9	**1.11**
Copper	5	190	0.03	190	0.03
Iron	1,440	1,000	**1.44**	1,000	**1.44**
Phosphorus	291.7	N/A	N/A	N/A	N/A
Selenium	2	2	**1.00**	2	**1.00**
Sodium	29,900	3,431,000	0.01	3,431,000	0.01
Strontium	3,570	10,700	0.33	10,700	0.33
Zinc	103.3	408	0.25	NV	NC

As identified in the tables above, an HQ>1 has been identified for chloride, cobalt, copper, iron, selenium, and zinc. These findings are based on the maximum surface water concentration measured for each COPC. A Tier 2 assessment is appropriate to take into consideration site-specific factors that impact toxicity and exposure. This may include such factors as occupancy and home range as well as whether the indicator species occupies the study area. An additional discussion for each of these COPCs is provided below.

Chloride

Chloride has been identified at concentrations up to 460 mg/L in surface water at the WWMF which exceeds: 1) the benthic invertebrate toxicity benchmark of 121 mg/L; and, 2) the aquatic invertebrate toxicity benchmark of 421 mg/L.

Benthic Invertebrates

A TRV of 121,000 µg/L was identified for benthic invertebrates which resulted in a hazard quotient of 3.8. The TRV was identified from benthic invertebrate toxicity values used in the development of the CCME Canadian water quality guideline [168]. The TRV is based on effects to the fingernail clam (Family Sphaeriidae), which is the most sensitive benthic invertebrate TRV (i.e., lowest TRV), with the exception of that for the endangered Northern Riffleshell Mussel which are located in southwestern Ontario and not within the vicinity of the Bruce nuclear site. Additional benthic invertebrate toxicity values (e.g., oligochaetes, freshwater mussels and amphipod) are ≥519,000 µg/L. As such, chloride concentrations do not exceed toxicity values protective of the other benthic invertebrate species evaluated by the CCME.

With regards to the Sphaeriidae family, benthic invertebrate analysis identified Sphaeriidae as being found in moderate abundance at SRD-1 (11.64%), SRD-4 (4.10%), WD-4 (11.23%) and WTL-1 (40.20%). These data provides evidence that reproduction and survival of Sphaeriidae occurs within the WWMF drainage system. Based on the presence of Sphaeriidae and since chloride concentrations are not greater than toxicity values identified for other benthic invertebrates, adverse impacts to the benthic invertebrate community from chloride are not anticipated.

Aquatic Invertebrates

Chloride toxicity to aquatic invertebrates was evaluated further, specifically with respect to the effect of water hardness. Aquatic toxicity studies were completed in [169] to support the development of the CCME guideline. The study identified that an increase in water hardness reduced the toxicity of chloride. The following relationship between an IC25 and hardness across a range of 10 mg/L to 160 mg/L was identified:

$$IC25_{(hardness\ x)} = 161 * \ln_{(hardness\ x)} - 281.73$$

The equation can be revised to:

$$Toxicity_{(hardness\ x)} = [Toxicity_{(hardness\ 80)}/IC25_{(hardness\ 80)}] * 161 * \ln_{(hardness\ x)} - 281.73$$

This relationship was identified for *Ceriodaphnia dubia*, and was considered appropriate for other cladocerans and potentially for other species.

Chloride concentrations in excess of 421 mg/L were identified only at SRD-1 where hardness has been determined to be ≥ 260 mg/L. The potential toxicity of chloride on aquatic invertebrates was assessed; a revised toxicity value was calculated using the hardness based equation provided by [169] for a water hardness of 160 mg/L, the upper limit of the hardness used in the development of the equation, and at a water hardness of 260 mg/L based on conditions at the Site. The toxicity value provided at 260 mg/L has an increased level of uncertainty and is only provided for context. The results of these calculations are provided in Table 4-52.

Table 4-52: Chloride TRVs Adjusted for WWMF Conditions

Species	Toxicity Value Identified in Study (mg/L)	Revised TRV based on Water Hardness		Adjusted HQ[3]
		160 mg/L	260 mg/L	
Daphnia magna	EC_{25} = 421	532	610	0.86
Ceriodaphnia dubia	IC_{25} = 454	535	614	0.86
Daphnia ambigua	LOAEL[1] = 440	556	637	0.83
Daphnia pulex	IC_{10}[2] = 368 IC_{27} = 441	465 557	532 638	0.99 0.83
Hyalella azteca	EC_{25} = 421	NC	NC	See text

1. Reduction in mean number of offspring by 13% [170].
2. The IC10 value is conservative in the context of identifying a toxicity value as the CCME considers an effect level of 10% or less of the exposed individuals to represent a no negative effect threshold. As such, the IC27 is also provided. The original study was conducted at a hardness of 100 mg/L [171].
3. Based on the maximum on-site chloride concentration of 460 mg/L and revised TRVs calculated at a water hardness of 160 mg/L.

NC = Not calculated.

The CCME identified an EC_{25} of 421 mg/L for *Hyalella azteca*. The water hardness in this study was not identified; although, it is anticipated to be approximately 125 mg/L based on the use of a standard artificial media [172]. Although an EC_{25} at a site specific water hardness could not be calculated, it would be reasonable that given the water hardness of 260 mg/L at SRD-1, the EC_{25} would be greater than 421 mg/L and likely greater than the measured concentration of 460 mg/L.

Based on the chloride toxicity values adjusted for hardness, adverse effects to aquatic invertebrates at the maximum WWMF concentration of 460 mg/L measured at SRD-1 are not likely. The sampling location supports about 2,000 individuals per m^2, including more sensitive species, e.g., Sphaeriidae and low numbers of *Gammarus fasciatus* (Amphipoda). Therefore, the risk of adverse impacts to the aquatic invertebrate community is low.

Cobalt

A HQ of 1.1 was identified for herpetofauna that are SARs (i.e., snapping turtle). This HQ is based on the maximum surface water concentration of 1 µg/L at GS-1 and a TRV of 0.9 µg/L. The maximum concentration was identified at one sample location during one sampling period (i.e., GS-1 in June 2013). This sampling location is within the area of the Grassed Swale. Subsequent sampling in this area (i.e., GS-1) has identified concentration ranging from 0.027 µg/L to 0.2 µg/L (i.e., in October 2013, April, 2014, May 2014, July 2014 and October 2014). Concentrations at other sampling locations ranged from 0.043 µg/L to 0.3 µg/L. Elevated concentrations of cobalt have not been observed in any other sampling location, nor in additional samples collected at GS-1. As such, elevated cobalt does not appear to be reflective of a baseline condition. Two (2) habitats supporting or having a high potential to support snapping turtles were identified (i.e., Turtle Wintering Areas and Amphibian Wetland Breeding Habitats). Neither of these habitats are within the vicinity of the grassed swale nor in the proposed WWMF expansion area. No adverse effects are considered to be present for the snapping turtle in association with cobalt in surface water.

Copper

A copper concentration in surface water was identified as exceeding the toxicity benchmarks for aquatic invertebrates in one sample, GS-1 in June 2013. The toxicity of copper is hardness-dependent. Hardness at GS-1 in June 2013 is estimated to be 315 mg/L. As identified in Section 4.3.4.1, the aquatic invertebrate toxicity benchmark was based on a cladoceran (*Daphnia pulex*) EC_{20} for survival at a water hardness of 57.5 mg/L. At a water hardness of 230 mg/L, the EC_{20} was 9.16 µg/L. The maximum concentration at GS-1 in June 2013 was 5 µg/L, which does not exceed a toxicity benchmark relevant to water hardness in this sample. Therefore likely adverse effects are not considered to be present for benthic invertebrates in association with copper in surface water.

Iron

An iron concentration in surface water was identified as exceeding the toxicity benchmark for fish and herpetofauna in one sample, at GS-1 in June 2013. As elevated concentrations of total iron have not been observed in any additional samples, it does not appear to be reflective of a baseline condition. The elevated concentrations of total iron may be associated with a surface water sample with a high level of particulate matter or anoxic conditions and the release of iron from sediment. Therefore likely adverse effects are not considered to be present for fish or herpetofauna in association with iron in surface water.

Phosphorous

Phosphorus is not considered toxic to aquatic organisms at levels and forms present in the environment. However, the addition of phosphorous to an aquatic system can result in increased plant and algal growth which can result in negative effects to the ecosystem. Phosphorous exceeded the guideline of 20 µg/L, representative of the highest phosphorous for a meso-trophic status (range of 10-20 µg/L). Given the varying aquatic habitats, this is a conservative assumption used for screening.

Phosphorous did not exceed 20 µg/L in the 2014 data set, but phosphorus concentrations measured in the EMP in 2013 exceeded this value. The EMP data set included samples from an area with low flow drainage and a depositional nature which are more representative of meso-trophic to eutrophic characteristics. Meso-eutrophic to eutrophic water bodies have phosphorous concentrations in the range of 20 µg/L to 100 µg/L [127]. In the EMP data set, which included three sampling periods, phosphorous was in the range of meso-eutrophic to eutrophic water bodies for all samples, with the exception of GS-1 (i.e., Grassed Swale) in June 2013 where a concentration of 291.7 µg/L was detected. It is noted that Grassed Swale underwent modification in May 2013. Some high TSS readings in the drainage from the swale were identified in May and August which were attributed to vegetation not being established during this time. Elevated phosphorous may have been associated with these modifications or anoxic conditions at the time of sampling and release of phosphorus from sediment. Elevated phosphorus does not appear to be reflective of a baseline condition. Based on the data set as a whole, no adverse effects are likely due to phosphorous.

Selenium

It is noted that selenium did not exceed the guideline of 2 µg/L, although selenium did exceed an alert level of 1 µg/L. The alert level of 1 µg/L has been identified due to the variability in bioaccumulation amongst aquatic systems. Selenium concentrations greater than 1 µg/L were only identified during one sampling round (i.e., GS-1 and SRD-3 in May, 2014). Given that selenium was not identified above 1 µg/L in any other sampling periods (including April and October, 2014) concentrations above 1 µg/L are not associated with long-term concentrations. Selenium concentration in sediment does not exceed an alert value of 2 mg/kg. Based on the data set as a whole, no adverse effects are likely due to selenium.

Zinc

Zinc concentrations in surface water were identified as exceeding the TRV for aquatic vegetation, aquatic invertebrates, and fish. The zinc TRVs identified in Section 4.3.4.2 are benchmarks based on lowest chronic values. Benchmarks are established to be conservative as they are to be protective of a wide variety of surface water conditions.

The aquatic toxicity of zinc is considered to be hardness-dependant; however, a single benchmark based on a LCV does not provide for a calculation to account for the effect of hardness.

The BC MOE has established the following hardness-based relationship for aquatic toxicity [173]:

$$\text{Adjusted TRV} = \text{TRV} + 0.75\ (\text{water hardness [mg/L } CaCO_3] - 90)$$

For chronic exposure, the BC MOE guideline was determined based on a study with a LOEL of 15 µg/L for aquatic invertebrates. Note that an uncertainty factor of 0.5 used by the BC MOE was not employed as the toxicity endpoint represents a LOEL. The US EPA [174] also provides a hardness-based equation of:

$$\text{Adjusted TRV} = e^{(0.8473[\ln \text{hardness}] + 0.7614)}$$

The resulting hardness-based concentrations are provided in Table 4-53. Zinc concentrations exceeding the lowest benchmark (i.e., 30 µg/L) were only identified in the EMP data set, specifically at SRD-2 and SRD-3. As such, concentrations at these locations are addressed in Table 4-53.

Table 4-53: Hardness-Adjusted Zinc Guidelines

Zinc Concentration (µg/L)	Location	Date	Water Hardness (mg/L $CaCO_3$)	BC MOE		US EPA	
				Hardness Adjusted Guideline (µg/L)	Adjusted HQ	Hardness Adjusted Guideline (µg/L)	Adjusted HQ
41.7	SRD-2	June 2013	248	133.5	0.31	229	0.18
52	SRD-2	May 2014	248	133.5	0.39	229	0.23
34.7	SRD-3	October 2014	179	81.75	0.42	174	0.20
103.3	SRD-3	May 2014	179	81.75	**1.26**	174	0.60

Based on the above information, it can be seen that the zinc concentration was in exceedance of the BC MOE hardness-based chronic value at SRD-3 in May 2014, but not the US EPA hardness-based chronic value. Samples taken upstream (SRD-1), downstream (SRD-4) and nearby (GS-1) in April 2014 and July 2014 did not identify similar elevated concentrations of zinc in surface water. The elevated zinc concentration at SRD-3 in May 2014 does not appear to be reflective of a baseline condition.

No likely adverse effects to aquatic vegetation and invertebrate communities or fish populations are anticipated based on zinc in surface water.

A TRV for herpetofauna SARs could not be identified based on the study using the Cope's gray treefrog. Laboratory studies with development and mortality reported in the database of reptile and amphibian toxicology literature (RATL) for zinc identified [175]:

- no developmental toxicity to the Jefferson Salamander based on exposure to 2000 µg/L;
- a protective effect against developmental effects to the Common toad based on exposure to 1000 µg/L;
- no decrease in survival to the Common toad at 4000 µg/L (65% survival at 32,000 µg/L); and,
- no developmental impact to the western toad at 100 µg/L (effects at 39,000 µg/L).

A study using the eastern narrowmouth toad identified concentrations of 100 to 100,000 µg/L resulting in a 3 to 7 % mortality and teratogenesis at hatching and a 5 to 14 % mortality post hatch. Details are not sufficient to discern at what concentration the effects occurred or if they are even greater than controls; however, a separate study by the same author using the eastern narrowmouth toad identified a LC1 of 600 µg/L [176]. It should be noted that the eastern narrow mouth toad is not found in Ontario. Based on the information provided in the RATL, adverse effects to SARs are not anticipated based on zinc concentrations at the WWMF.

For the above COPCs in surface water, it is noteworthy that the maximum concentration for cobalt, copper, iron and phosphorus are all associated with a single water sample collected from GS-1 in June, 2013. As noted above, the Grassed Swale underwent construction into a storm-water runoff management system in 2013. Effluent monitoring was conducted during and following the construction of the grassed swale. Construction ended in May 2013. High TSS results were identified in the June and August samples. It was reported that the high TSS were a result of vegetation along the banks of the reconstructed swale not being established until the fall of 2013. Elevated TSS was not identified in October, 2013. High TSS measurements in June 2013 may have contributed to elevated metal concentrations measured in surface water at GS-1 in June 2013, as may have a period of stagnation as discussed previously.

4.3.5.3 Aquatic Receptors-Risks due to Exposure to Sediment

The approach for developing the weight of evidence (WOE) for the risk characterization was developed using the Federal Contaminated Sites Action Plan (2012) guidance [177]. Risk characterization was completed as a WOE for each water body. The lines of evidence include: 1) the comparison of exposure concentrations to benthic invertebrate toxicity values; and 2) a qualitative evaluation of benthic invertebrates abundance and diversity. The general format is a matrix that evaluates magnitude, causality, and ecological relevance for each line of evidence and presents an overall WOE rating. Potential risks to benthic invertebrates is based on a community endpoint. The aquatic habitats for which data are evaluated are located within an industrial area. The SRD and West Ditch both serve as industrial drainage ditches. Taking into consideration the aquatic habitat present, the protection goal is to maintain a benthic invertebrate community that would be characteristic of the on-Site industrial drainage system habitat. The criteria used to score each line of evidence is provided in Appendix F, along with the weight of evidence evaluation tables for the SRD, Wetland and West Ditch respectively. Each line of evidence is discussed below.

To support the comparison of exposure concentrations to benthic invertebrate toxicity values, the HQs are summarized in Table 4-54.

Table 4-54: Risk Estimate to Benthic Invertebrates from Sediment COPCs

Parameter	Maximum Concentration (mg/kg)	TRV (mg/kg)	HQ
Arsenic	7.42	17	0.44
Copper	156.5	149	**1.05**
Manganese	1190	732	**1.63**
Molybdenum	26.2	25	**1.05**
Silver	15.55	1.7	**9.15**
Sodium	1490	4000	0.37
Strontium	1130	1781	0.63
Tungsten	0.3585	960	0.0004
Zinc	730	459	**1.59**

South Railway Ditch

Data used in the evaluation of risks to benthic invertebrates in the SRD included sediment chemistry data from four sampling locations (SRD-1, SRD-2, SRD-3 and SRD-4) on two separate sampling events for each location; and, benthic invertebrate field data from two locations (SRD-1 and SRD-4)[23]. Based on the toxicological component of the evaluation, a HQ of <1 was identified for arsenic, silver, sodium, strontium and tungsten.

At SRD-1, copper had a HQ of essentially 1 (i.e., 0.99 and 1.05 for April and October, respectively) representing a low to moderate potential for effects. The HQ is based on the consensus-based PEC of 149 mg/kg, above which concentrations are expected to be toxic more often than not. No concentrations exceeded the CNSC SEL of 269 mg/kg. All other sampling locations had a HQ<1 for copper. Note that SRD-1 is located a short distance upstream of the WWMF where elevated COPC concentrations have been identified in surface water, and a historical spill has occurred.

At SRD-1 zinc had a HQ of 1.5 and 0.9, for April and October, respectively. At SRD-4, a HQ of 1.6 and 0.25 were identified for April and October, respectively. Like copper, the TRV for zinc is a consensus-based PEC (459 mg/kg). Hence, zinc represents a low to moderate potential for effects at SRD-1 and SRD-4. All other sampling locations had a HQ<1 for zinc.

The potential for adverse effects from sediment-associated copper and zinc concentrations at SRD-1, upstream of the WWMF, appears to be associated with activities at the SSTF, including a historical spill. Sediment concentrations at SRD-2 and SRD-3 are lower and do not exceed the TRVs, probably because this section of ditch has been dredged in 2006.

Elevated zinc concentrations in sediment at SRD-4 may be associated with the corrugated steel culvert that runs under Siding Road near WTL-1 and a second culvert

[23] Sampling locations SRD-2 (SED-C) and SRD-3 (SED-E) are associated with WWMF EMP sampling events, which did not include benthic invertebrate sampling.

in the ditch parallel to Siding Road. Zinc is a known component of corrugated steel piping, and the culverts are a source of zinc, with aqueous zinc concentrations increasing up to a factor of five between WTL-1 and SRD-4, and sediment zinc concentrations increasing by a factor of 3.5. At SRD-4, manganese had a HQ of 1.63 based on a background value of 732 mg/kg in April 2014. However, concentrations above background were not identified at this location in October, 2014. No other sampling locations had concentrations greater than background for manganese. Based on the data, it is possible that the elevated manganese concentration is anomalous.

At SRD-4, molybdenum had a HQ of essentially 1 (i.e., 1.05 in April 2014). Considering that the HQ is based on a minimum effect level, the potential for an adverse effect is low. All other sample locations had a HQ<1 for molybdenum.

Sediment samples were not collected downstream of SRD-4 in 2014. However, as part of the DGR EA [112], sediment samples were collected in 2009 at a downstream location, SW4, between SRD-4 and Stream C (location 2009 SW4 on Figure 2-39) and at SW2 in Stream C (location 2009 SW2 on Figure 2-39). At location SW4, copper and zinc concentrations exceeded the sediment screening values, but were less than the TRVs. No exceedances of sediment screening guidelines occurred at SW2 in Stream C. Neither manganese nor molybdenum sediment concentrations exceeded guidelines downstream of SRD-4 at SW4 or in Stream C at SW2.

Benthic invertebrate family richness and diversity were identified as being low and the community consists of facultative species or organic pollution tolerant species that can tolerate low oxygen conditions. Taking into consideration the aquatic habitat is an industrial ditch, it is difficult to assess whether the limited benthic community is strictly the product of poor quality habitat or if elevated sediment copper and zinc concentrations are having an effect. In the South Railway Ditch a large portion of the total metal concentration in both the water column and surficial sediments is probably not bioavailable. Under oxic conditions metals may be lost from the water to sediment with binding to various ligands such as metal oxides (iron oxides and manganese oxides), organic matter, and carbonates greatly reducing their availability to biota. During periods of low flow or no flow (stagnation) near anoxic conditions may develop in the water column and under reducing conditions in the sediment redox sensitive metals (iron and magnesium and co-precipitated metals) may be released from sediment to the porewater and diffuse back into the water column or bind strongly to other ligands in the sediment such as organic matter and sulphide [193]. The net effect being an overall reduction in the availability of the metals for uptake by biota.

<u>Wetland</u>

Data used in the evaluation of risks to benthic invertebrates in the Wetland included sediment chemistry data from two sampling locations (GS-1 and WTL-1) on two separate sampling events for each location; and, benthic invertebrate field data from two locations (GS-1 and WTL-1).

Based on the toxicological component of the evaluation, no sediment concentrations were identified above the TRV. The benthic community indices (richness, diversity and HBI) indicate that the habitat quality is very poor and that severe organic loading from decay of plant material and anoxic conditions are likely. No additional benthic invertebrate evaluation in the Wetland area is recommended.

West Ditch

Data used in the evaluation of risks to benthic invertebrates in the West Ditch included sediment chemistry data from one sampling location (WD-4) on two separate sampling events; and, benthic invertebrate field data from one location (WD-4).

Toxicity data indicate the potential for effects associated with silver concentrations. The benthic indices indicates a poor quality habitat within West Ditch. The benthic community results suggest a stressed benthic community, as may be expected in a drainage ditch, but with a higher invertebrate density and family richness than other sites along with the presence of several organic pollution sensitive families. The latter is probably the reflection of the presence of flowing water year round and stable substrate of bedrock and rock armouring at WD-4. Silver in sediment is likely present as organo-metallic complexes due to the availability of organic carbon in the system, reducing its bioavailability and toxicity to benthic invertebrates.

The sampling location in the West Ditch is not within the WWMF and WWMF-related data have not identified a WWMF source of silver that may impact the West Ditch. As such, no additional recommendations are made with respect to the West Ditch.

4.3.5.4 Terrestrial Birds and Mammals

Based on the estimated exposure concentrations and TRVs presented in Sections 4.3.3.3 and 4.3.4.4, exposure ratios are provided for dioxin and furan exposure to birds and mammals in Table 4-55. The LOAEL TRVs are used in the assessment of non-SAR receptors; NOAEL TRVs are used in the assessment of SAR receptors as they represent a more restrictive level. The NOAEL risk estimates have only been performed for those receptors which are SARs or surrogate SARs.

The HQ was found to be less than one with the exception of the HQ for the little brown bat. Although a HQ>1 has been identified, uncertainties associated with the exposure and toxicity assessment are expected to overestimate risk. Specifically for the bat:

- The TRV employed in the toxicity assessment is a NOAEL; exceedance of this value does not necessarily indicate that an adverse effect is likely (i.e., the NOAEL represents a no observed adverse effect level). The identification of the NOAEL and LOAEL values are dependent on the study design used for the TRV development and the exact concentration at which effects may start to be observed is >NOAEL and ≤LOAEL. Exposure for the little brown bat is >NOAEL but <LOAEL;
- In the exposure calculation, earthworms are used as a surrogate for flying insects. Flying insects are adult insects and consist of both terrestrial insects whose larval stages develop either on foliage or in the soil, and aquatic insects that develop in the wetlands or the ditches. The use of earthworms as a surrogate for flying insects is considered to be conservative since COPC concentrations in earthworms generally are greater than that in flying insects. For example, concentrations of dioxins and furans in crickets were found to be 0.36% and 11%, respectively, of that in earthworms [178], whereas PCB concentrations in above-ground invertebrates were 20% of that observed in earthworms [179]. If it was assumed that flying insects at the WWMF had 20% of the concentration found in earthworms, then the HQ would be reduced to 0.55;
- The average soil concentration is 7 pg/g, which is considered background by the Ontario MOE.

No adverse effects are likely due to potential dioxin and furan exposure from soil in the little brown bat.

Table 4-55: Risk Estimates for Birds and Mammal for Dioxin and Furan Exposure

Receptor	Average Daily Dose (mg/kg/day)	LOAEL TRV (mg/kg/day)	HQ	NOAEL TRV (mg/kg/day)	HQ (SAR)
Red-Eyed Vireo*	3.15E-06	1.40E-04	0.02	1.40E-05	0.23
American Robin*	6.17E-06	1.40E-04	0.04	1.40E-05	0.44
Wild Turkey	1.20E-07	1.40E-04	0.001	-	-
Bald Eagle	1.94E-07	1.40E-04	0.001	1.40E-05	0.01
Short-tailed Shrew	3.87E-06	1.00E-05	0.39	-	-
Little Brown Bat	2.77E-06	1.00E-05	0.28	1.00E-06	**2.8**
White Tailed Deer	6.68E-09	1.00E-05	0.0007	-	-
Red Fox	4.28E-06	1.00E-05	0.43	-	-

*Surrogate SARs

4.3.5.5 Herpetofauna – Soil Exposure

Exposure and risks associated with COPCs in the aquatic habitat is addressed in Section 4.3.5.2.

In the terrestrial habitat, the only COPC is dioxins and furans in soil. Sampling locations with dioxin and furan levels that exceed the provincial background level of 7 pg/g are A2-2 and A4-2. Sampling location A2-2 is next to a building and storage containers, and is used as a road or driveway. Sampling point A4-2 is located in Area 4, which is a cleared area that appears to be used for storage and parking. There is no amphibian habitat in these areas. There is the potential that turtles may cross these areas of the site while searching out aquatic habitats. However, any time within these areas would be limited.

4.3.5.6 Aquatic Birds and Mammals

Based on the estimated exposure concentrations and TRVs presented in Sections 4.3.3.4 and 4.3.4.3, exposure ratios are provided in Table 4-56 for aquatic birds and mammals.

Table 4-56: Risk Estimates for Aquatic Birds and Mammals

COPC	Mallard Duck			Bald Eagle			Muskrat		
	Average Daily Dose (mg/kg/day)	TRV (mg/kg /day)	HQ	Average Daily Dose (mg/kg/day)	TRV (mg/kg /day)	HQ	Average Daily Dose (mg/kg/day)	TRV (mg/kg/day)	HQ
Aluminum	3.92E+01	109.7	0.357	6.04E-02	109.7	0.0006	7.11E+01	19.3 (water); 100 (food/sediment)	0.71
Arsenic	4.10E-02	7.4	0.006	1.43E-02	2.24	0.0064	1.35E-01	1.3	0.104
Chloride	1.25E+04	NV	NC	2.72E+03	NV	NC	1.96E+04	NV	NC
Cobalt	3.96E-01	7.8	0.051	6.80E-03	7.61	0.0009	6.14E-02	8.8	0.007
Copper	3.59E+00	15.7	0.229	4.44E-01	4.05	0.11	1.01E+00	15	0.067
Iron	2.54E+02	56	**4.5**	1.03E+01	25	0.412	1.59E+02	544	0.293
Manganese	1.27E+02	977	0.130	9.72E+00	977	0.0099	1.78E+01	284	0.063
Molybdenum	3.79E-02	35	0.001	6.28E-02	3.5	0.018	8.37E-02	2.6	0.032
Selenium	3.10E-01	0.3	**1.0**	3.24E-02	0.2	0.16	3.62E-02	0.33	0.110
Silver	2.56E-02	20.2	0.001	5.51E-05	2.02	0.00003	6.45E-02	60.2	0.001
Sodium	7.25E+02	NV	NC	3.15E+03	NV	NC	2.81E+02	NV	NC
Strontium	2.30E+02	NV	NC	1.04E+00	NV	NC	2.05E+01	633	0.032
Tungsten	NC	NV	NC	5.71E-03	NV	NC	NC	NV	NC
Zinc	9.63E+01	109	0.883	2.66E+01	66.1	0.40	1.15E+01	320	0.036

A quantitative evaluation of strontium for birds and tungsten for birds and mammals could not be completed due to a lack of suitable TRVs. Strontium and tungsten have not been identified as representing a risk to aquatic receptor groups (e.g., plants, invertebrates and fish) and are not anticipated to result in toxicity to birds or mammals. Within the ecological risk assessment framework, contaminants which are not bioaccumulative and that are not toxic to aquatic receptor groups are not anticipated to be toxic to birds and mammals.

For the bald eagle and the muskrat, the HQ was found to be less than one for all contaminants; therefore no risks have been identified to the bald eagle or the muskrat for non-radiological COPCs and no further analysis is required. Sodium and chloride, however, did not have suitable TRVs; an assessment of these contaminants can be found below.

For the mallard duck, an HQ>1 has been identified for iron. These findings are based on a 95th UCLM surface water concentration and a 90th percentile sediment concentration for iron; therefore they are conservative. In addition, the calculation of the HQ does not take into consideration that the wetland is poor quality habitat without large pools of water and, therefore, is not preferred habitat for mallard brood rearing. Baseline studies also indicate the wetland is infrequently visited by ducks. Additional discussion has been provided below.

<u>Iron</u>

An iron HQ of 4.5 was identified for the mallard duck. Risks associated with iron are driven by the sediment ingestion and food ingestion exposure pathways. It is considered that the risks are a function of conservatisms associated with estimated concentrations in food items and the TRV.

The iron sediment concentration used in the exposure assessment was 17,900 µg/g and the iron concentration in surface water is 343 µg/L. For context, iron concentrations in sediment are less than background concentrations (i.e., sediment 98th percentile of 23,461 µg/g). The average surface water iron concentration in the Great Lakes was 120 µg/L in 1976, with concentrations of 300 µg/L to 700 µg/L near industrial sources [180]. The surface water exposure concentration only exceeds the guideline of 300 µg/L by 14%. It is also noted that surface water guidelines for total iron for many jurisdictions (including the US EPA and BC MOE) is 1,000 µg/L.

Estimated food concentrations are likely to be conservative. Iron concentrations in surface water are based on total concentrations which includes particulate matter and is not necessarily reflective of concentrations which are bioavailable for uptake. In addition, uptake factors are inversely related to concentrations in water [181]. As such, with higher surface water concentrations (as identified at the WWMF) the uptake factors become more conservative and overestimate exposure. The estimated concentration in vegetation is 8 times greater than measured concentrations in the cattail. The estimated concentration in aquatic invertebrates is also likely to be overestimated.

The TRV is based on studies in which birds are exposed to iron in food for the purpose of reducing the toxic effects of a natural component of cotton seed meal [161]. As such, iron is provided in the toxicity study in a bioavailable form which is likely to be greater than the bioavailability of iron within the natural environment.

Based on the iron exposure concentrations, and the discussion provided above, toxic effects associated with iron for the mallard duck are not anticipated.

<u>Sodium and Chloride</u>

The ability to quantitatively assess potential risks with sodium and chloride is complicated by the lack of suitable TRVs and uncertainty in exposure through the food chain. Sodium and chloride are essential for animals and are not commonly considered to cause toxicity. However, further discussion is provided for the aquatic birds and mammal (i.e., mallard, bald eagle and the muskrat)

Sodium and chloride have been identified separately as COPCs in surface water. The maximum estimated concentration of sodium chloride is 709 mg/L, based on sodium being the limiting factor in the formation of sodium chloride.

Muskrat

Sodium and chloride are the predominant ions that impact salinity. Other substantial ions include magnesium, calcium, and sulfate. In fresh water, salinity is nearly zero. In oceans, the salinity is about 35 g/L. The mixture of seawater and fresh water in estuaries is called brackish water and its salinity can range from 0.5 to 35 g/L [182].

Muskrats are known to inhabit estuarine habitats (e.g., brackish and salt water with salinity of up to 35 g/L), indicating that sodium chloride at 0.709 g/L at the Site would not result in toxic effects to the muskrat. However, in the evaluation of habitat quality to support muskrats it is important that the chemical composition of the surface water supports a food source. A value of 30 g/L salinity is provided in regard to the protection of food sources for the muskrat, although this value is relevant to the specific plant species addressed in the habitat evaluation [183]. Cattails are abundant at the site and chemical composition of water at the Site has not been identified as limiting growth of this food source. As such, adverse effects associated with muskrats in association with sodium and chloride are not anticipated.

It should be noted that an active muskrat lodge was observed in the Wetland Complex in the past, however, water levels in the Wetland Complex no longer provide suitable overwintering habitat for the muskrat. Additionally, the SRD is not of sufficient depth to support muskrat overwintering.

Birds

With respect to birds, toxicity associated with sodium chloride has been identified at concentrations greater than 4000 mg/L in water and 27,000 mg/L in the diet [184]. Sodium chloride concentrations in water at the WWMF are lower than toxic levels (i.e., maximum sodium chloride concentration of 709 mg/L). Estimated concentrations in food items are greater than 27,000 mg/L based on uptake factors; however, these estimates are likely to be conservative given the ability of plants and animals to regulate sodium.

With regards to diet, fish (fillets) commonly have sodium concentrations of <1176 mg/kg wet weight (4,700 mg/kg dw) [185]. This is of a similar magnitude to sodium concentrations of 2,890 to 3,580 mg/kg dw that were identified in three fish species exposed to sodium concentrations in surface water of 8,900 mg/L to 9,300 mg/L, which is higher than present on-Site [186]. The sodium concentration measured in plants on site (i.e., cattails) was of 1,654 mg/kg dw (i.e., highest mean value). Based on this information, food items would be expected to contain between 1,654 to 4,700 mg/kg dw sodium, or 4,204 to 11,948 mg/kg dw sodium chloride. The food item concentrations are less than sodium chloride concentrations in the diet (i.e., 27,000 mg/kg) associated with toxicity to birds.

Based on the evaluation provided above, adverse effects in birds and mammals as a result of sodium and chloride in surface water and sediment at the WWMF is not anticipated.

4.4 Assessment of Physical Stressors

4.4.1 Screening Criteria

Physical stressors will be evaluated qualitatively. Therefore no criteria have been identified.

4.4.2 Screening

For ecological receptors, the physical stressors considered include:

- Sensory disturbance (light, noise); and,
- Mortality (road kill and/or bird strikes).

Physical stressors such as loss of habitat, dust generation, entrainment/impingement of aquatic biota, and thermal releases to the aquatic environment are not applicable to the existing conditions at the WWMF.

4.4.3 Effects Assessment

A qualitative assessment was performed to determine the impact of physical stressors. No benchmark data are available for mortality (road kill and/or bird strikes).

4.4.4 Risk Characterization

4.4.4.1 Mortality – Road Kill

Data on deer mortalities have been collected at the Bruce nuclear site between 1998 and 2012 (Figure 4-5) [26]. The data range from 4 to 13 collisions per year and 0 to 6 mortalities per year, with the highest deer collision and mortality occurring in the first year of monitoring (1998). Overall, collisions and mortalities have shown a decreasing trend during the monitoring period [26] despite increased traffic during the large construction projects on site (i.e., refurbishment of Unit 1 and Unit 2 at BNGS-A) and increased security vehicle activity during this monitoring period. Deer mortalities are limited by traffic control; posted speed limits are strictly adhered to by all site personnel. In addition, collisions and mortalities are likely limited by the 10 ft. fencing (with barbed wire) currently surrounding the entire Bruce nuclear site, which inherently has reduced the movement of deer onto the site from the Huron Fringe

Deer Yard. Subsequently, collisions and mortalities are generally considered to be uncommon events.

Deer sightings were uncommon and sporadic during the baseline surveys; however, deer are routinely observed on site by Bruce Power and OPG staff. The Huron Fringe Deer Yard overlaps within the eastern edge of the Bruce nuclear site, but is located outside of the WWMF (see Figure 4-6) and the surrounding OPG retained lands. Based on the reduction of deer collisions and mortality since 1998, the mitigation measures that have been implemented to reduce deer-vehicle interactions, and the installation of the fencing around the entire Bruce nuclear site, operation of the WWMF is unlikely to represent a risk to deer and is not likely to be significant. No further analysis is required.

Amphibians are also at risk of road mortality while travelling between breeding areas and summer habitats. Spring peepers and northern leopard frogs were identified in habitats surrounding the WWMF and the WWMF potential expansion areas. No data on amphibian mortality is available for the Bruce nuclear site; however, some level of mortality is likely occurring due to vehicle traffic. The overall number of these species was considered high within close proximity to the WWMF and the WWMF expansion areas, suggesting road mortality is not a threat to local population of amphibians within the Terrestrial Monitoring Area. Therefore, amphibian mortality due to vehicles is considered to be negligible.

4.4.4.2 Mortality – Bird Strikes

Window strikes are the largest known human-related cause of mortality to birds and are estimated to kill 97 to 976 million birds per year [187]. Birds perceive mirrored habitat in the window as 'natural' habitat (or simply do not see the glass) and fly directly into the window, causing injury and/or death. No data for bird collisions with project structures are available for the WWMF; however, based on bird collision information available from Pickering NGS [188], bird mortalities due to collisions with site structures are rare events, and therefore the risks are not considered to be significant. The structures on the WWMF are largely low-level buildings primarily constructed of cement, siding, or other non-glass material. Therefore, collisions with these buildings are expected to be negligible and would not represent a stressor to resident or migratory bird species. Bird collisions with WWMF structures are not considered to represent an adverse effect. No further analysis is required.

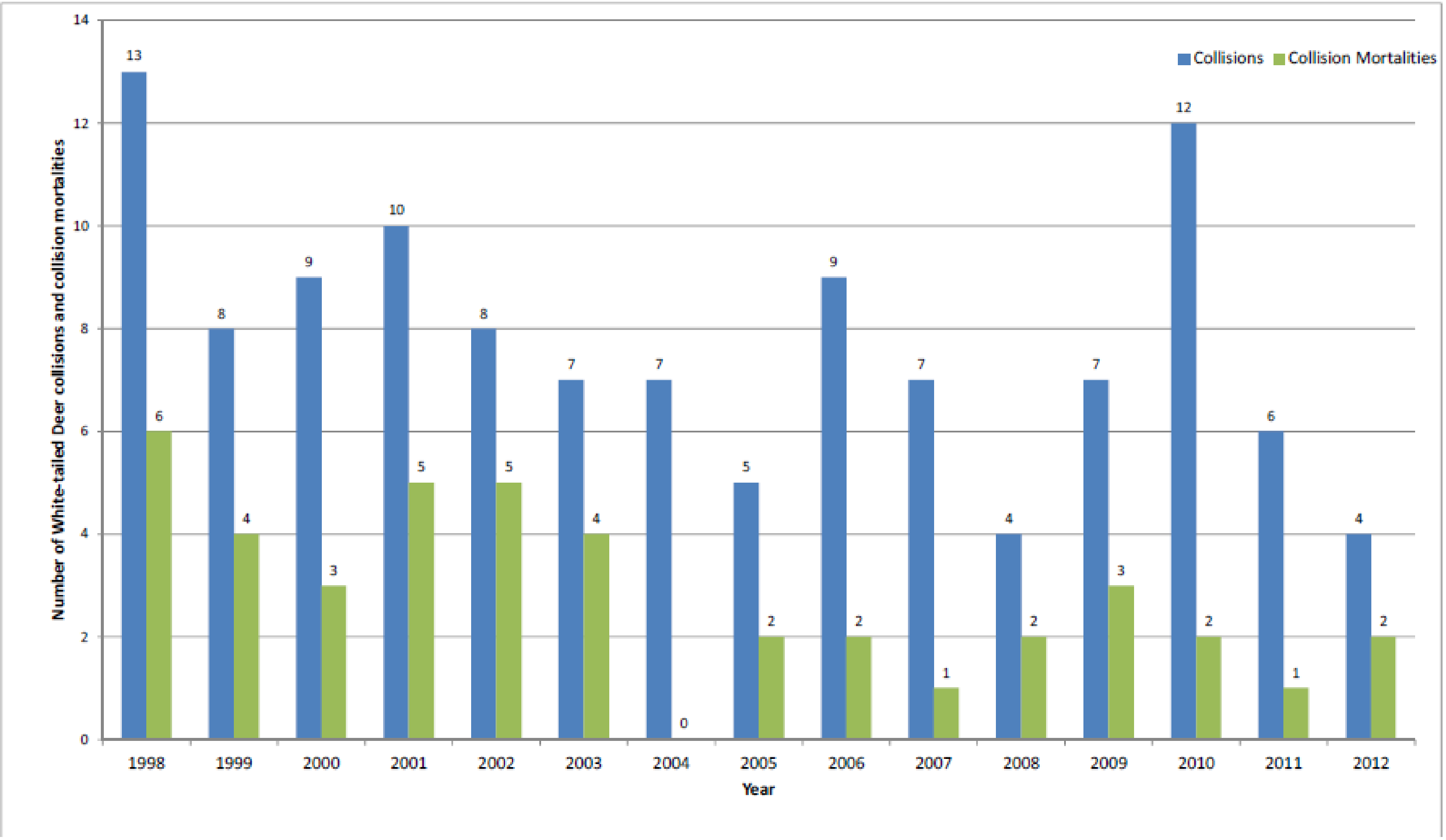

Figure 4-5: Number of Bruce Power White-tailed Deer Collisions and Collision Mortalities [26]

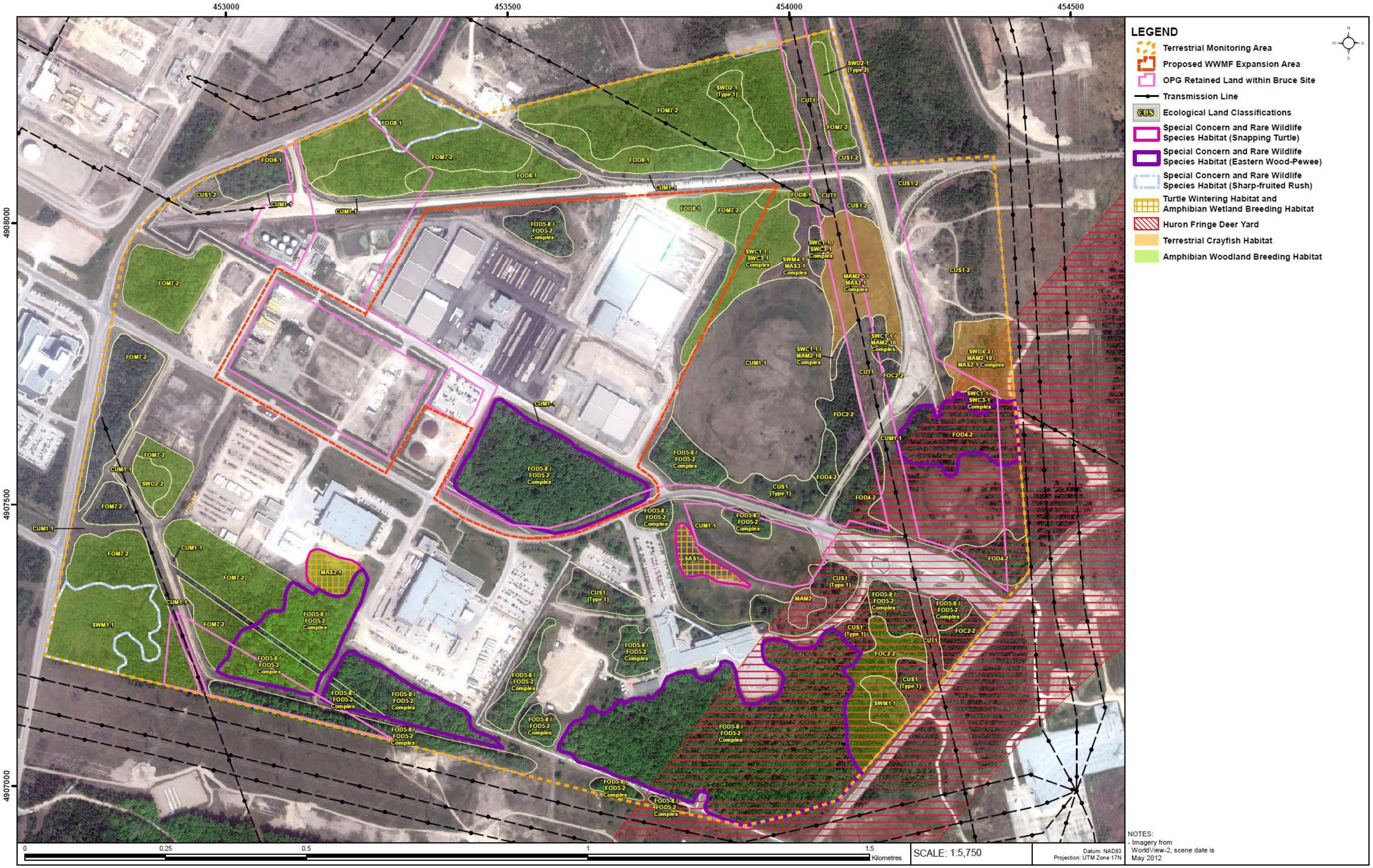

Figure 4-6: Huron Fringe Deer Yard

4.4.4.3 Light

Artificial night lighting has the potential to interact with receptors (birds, mammals and amphibians) through habitat avoidance, changes in rates of predation and mortality, and/or changes in food resource availability [189]. Interior and exterior lighting on tall buildings and decorative lighting on all structures tends to confuse birds. Night migrants use the stars as navigational tools and may mistake building light sources as celestial lights. The situation is exacerbated during foggy or rainy weather when cloud cover is low and birds fly at lower altitudes. Birds can also become "entrapped" by light sources. Once inside a beam of light, they are reluctant to fly out into the darkness, and they will continue to fly around within the light beam. Fatigue sets in, collisions with other birds or the structure occurs, or the birds simply collapse from exhaustion. They frequently die from injuries or fall prey to predators. For small, nocturnal, herbivorous mammals, artificial night lighting may increase risk of being killed by a predator and decrease food consumption. Circadian rhythms and melatonin production may also be disrupted by artificial night lighting, whereas for larger mammals, night lighting may increase vehicle collisions and can disrupt dispersal movements and corridor use. Amphibians (frogs) are affected through changes in calling rates, changes in frog prey or predation interactions, and tadpole survivorship.

Artificial night lighting at the existing WWMF is not considered to represent a risk to receptors. Artificial night lighting at the existing WWMF facility is limited and not far reaching, and the presence of birds, mammals and frogs within the immediate vicinity of the WWMF facility would suggest that wildlife species currently using these areas are habituated or not detrimentally affected by artificial night lighting associated with the WWMF facility. During the baseline surveys, high numbers of migrant species were observed during the migration periods (spring and fall) and no local deviations of expected migration route or stressed birds were observed during migration. In addition, there was no observed or recorded correlation between light sources and bird collisions, and there were no tall continuous artificial light structures identified in frog breeding habitat. As such, no further analysis is required.

4.4.4.4 Noise

Based on the 2015 spot measurement noise sampling, birds and other wildlife in the vicinity of the WWMF are currently experiencing L_{EQ} noise levels ranging from 64 to 76 dB within and in the immediate vicinity of the WWMF (Table 4-57, Figure 4-7) during the morning hours (6 am to noon, peak bird activity). Locations designated as "ER#" are similar locations to the spot noise measurements stated in the DGR EA. Although these noise levels are based on a sample day, it is expected that these levels would be representative of typical operations and therefore the noise impact to birds and other wildlife would not vary significantly day to day.

It is assumed that all of the 2014 breeding bird baseline surveys were conducted within areas exposed to L_{EQ} noise levels between approximately 64 and 76 dB, the species recorded (including SAR and species of conservation concern) have either acclimated to current noise levels and are able to successfully continue biological processes (e.g., mate selection, nesting, foraging), or are inherently tolerant to noise levels of this range. This is supported by the results of the survey conducted in 2014.

For example, on average, 12.5 bird species were observed per point count and 17.7 total birds were observed per point count. These are very normal numbers for bird survey results. In addition, 86 species of birds were recorded during migration for a total of 1,357 total birds over 4 days of surveys (approximately 32 hours of surveys). Acclimation and tolerance to noise levels of this range may be a result of the variable nature of the noise disturbance around the WWMF since the 2015 modelling identified approximately a 12 dB variation in noise levels at these locations and the DGR EIS [5] noted that existing noise levels vary by as much as 39 dB depending on the time of day. Based on these findings, the operation of the existing WWMF is unlikely to represent a noise disturbance beyond tolerance on species currently occurring within the vicinity of the WWMF.

Table 4-57: 2015 Linear Noise Levels, Ecological Receptors

Location	2015 L_{EQ} Noise Levels (dB)
1	64
2 (ER7)	69
3 (ER4)	67
4	67
5	76
6 (ER3)	65
7	76
8 (ER5)	69
9 (ER6)	66
10	64

Figure 4-7: Noise Monitoring Locations

4.5 Uncertainties in the Ecological Risk Assessment

4.5.1 Uncertainties in the Monitoring Data

The principle sources of uncertainty in the measured physical parameters and non-radiological and radiological baseline data include:

- Inherent data variability, including temporal and spatial heterogeneity;
- Sampling uncertainty, including location, collection, transfer and handling of samples; and,
- Analytical uncertainty, including sample preparation, instrumentation and method uncertainties.

Overall baseline characterization strategies were built using the extensive data available for the WWMF and were designed to address the remaining data gaps. The sampling program was designed to ensure that data variability is captured and to minimize systematic uncertainty.

The sampling program was implemented using current industry standards and procedures. The sampling procedures were designed to minimize sampling uncertainty. A quality program was also used to minimize potential systematic uncertainty in data collection and analysis.

4.5.2 Uncertainties in the Screening Assessment

Sources of uncertainty during the problem formulation and screening phase include the conceptual model and the screening criteria. Uncertainty in the conceptual model includes the assumption that certain pathways are not significant.

Maximum contaminant concentrations in each medium determined from two sampling programs were used in the screening assessment. The measured maximum concentrations were sufficiently below guideline values, or have no true guideline values and have been compared to background concentrations. Therefore the level of uncertainty in the screening assessment is considered to be acceptable and will not impact the conclusions of this step.

4.5.3 Uncertainties in the Exposure Assessment

4.5.3.1 Non-radiological Exposure Assessment Uncertainty

Uncertainties in the exposure assessment include the representativeness of media concentrations used in the assessment at each location and the exposure parameters used in the model. Maximum concentrations found in the WWMF were used as an upper bound of exposure. These values are, by definition, not representative for mobile organisms that can move around the site and effectively average their exposure concentrations.

However, the use of maximum concentrations for the exposure assessment results in a bounding and conservative dose to each indicator species.

4.5.3.2 Radiological Exposure Assessment Uncertainty

The radiological exposure to indicator species was calculated using concentrations measured by various monitoring programs, with the exception of air concentrations, which were modelled. Where radionuclides were measured at levels below the detection limit, 50% of the detection limit was assumed as per CSA N288.6-12, Clause 7.3.3.3 [2], consistent with previous ERAs ([5], [6], [70], [76]).

The code IMPACT was employed to estimate air concentrations which were used to calculate doses to non-human biota. There is uncertainty associated with the code regarding air dispersion calculations. However, exposure to airborne radionuclides represents a minor pathway to non-human biota. In addition, the dose to non-human biota is a small fraction of benchmark value for each indicator species considered. Therefore, the uncertainty associated with the IMPACT code has no impact on the conclusions of the EcoRA.

The maximum values that were available in each medium were used as values that were representative for the entire WWMF, which represents a conservative assessment.

4.5.4 Uncertainties in the Effects Assessment

Toxicological benchmarks used in the risk assessment were selected from sources recommended in CSA N288.6-12 [2]. Where values were not available from these sources, appropriate values were determined from literature sources.

There is inherent uncertainty in predicting toxicological responses from literature studies rather than directly measuring toxicity at the Site; therefore there is some uncertainty associated with TRVs. In most cases, TRVs are assumed to be conservative; i.e., no toxicity is anticipated if Site concentrations are below benchmarks. This is because most reference values are based on the most sensitive species tested or on a similar low effect level (e.g., 10th or 25th percentile of species sensitivity distribution), and the toxicity tests upon which they are based are typically conducted under conditions that maximize toxicity (i.e., the use of soluble metal salts). The use of NOAEL in the assessment of risks to SAR is likely to overestimate risks.

Radiation dose benchmarks for biota are values as recommended by CSA N288.6-12 [2]. These values are based on controlled laboratory studies and demonstrated low levels of effect, rather than using values based on field studies.

4.5.5 Uncertainties in the Risk Characterization

There are uncertainties associated with the components contributing to the overall risk assessment. This includes receptor exposure factors, such as transfer factors, intake rates and bioaccumulation factors, partition coefficients, dose coefficients and averaging assumptions, as well as benchmark values used to determine the risk of potential effects.

4.5.5.1 Non-radiological Risk Characterization Uncertainty

Overall, considering uncertainties in the exposure assessments and the benchmark values, it is reasonable to consider that HQs above 1 for a COPC and receptor are indicative of a potential for adverse effects. However, it does not necessarily imply adverse effects; i.e. the potential for adverse effects does not necessarily mean toxicity is occurring at the site. No toxicity studies were performed at the site. In many cases, adverse effects at a site may be absent or much lower than that predicted from laboratory studies. For example, the high levels of water hardness and alkalinity characterizing WWMF surface waters will have an ameliorating effect on metal toxicity.

However, given that maximum concentrations in media were used to determine the exposure doses, uncertainty in the risk characterization is not considered to impact the conclusions of the assessment.

4.5.5.2 Radiological Risk Characterization Uncertainty

The maximum values that were available in each medium were used as values that were representative for the entire WWMF. The estimated doses resulting from these maximum concentrations are a small fraction of the benchmark values; therefore any uncertainty in the calculations or the data does not impact the conclusions.

4.5.5.3 Physical Stressor Risk Characterization Uncertainty

Unpredictable events such as changes in predator-prey relations, disease, or stochastic weather events (e.g., heavy snowfall), could result in changes to deer movement through the Bruce site and thus result in changes (either positively or negatively) to vehicle collisions with deer. However, population levels are assumed to be stable at the WWMF suggesting incidences of vehicle collisions would continue at the levels previously recorded at the site. Given the management measures in place to mitigate road mortality for deer, including reduced speed limits and fencing, there is a limited level of uncertainty with respect to the risk evaluation for deer mortality due to vehicle collisions.

Amphibian movements from breeding areas to summer habitats are typically associated with vegetated corridors; however, no significant amphibian corridors were identified within the vicinity of the WWMF site. Roads through the Bruce site represent a physical barrier to movement of amphibians, although some amphibians will venture across roads with high risk of mortality and/or desiccation. As changes in the general road network and the movement of vehicle are assumed to remain consistent at the WWMF site, changes in amphibian mortality due to vehicles are predicted to remain consistent. As such, there is a low level of uncertainty with respect to the risk evaluation for amphibian road kill.

Given that collisions with the solid buildings (non-glass) are extremely rare events and that data from the Pickering NGS indicate that bird mortalities due to collisions with site structures are rare events [188], uncertainty with respect to the risk evaluation for bird strikes does not impact the conclusions.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Human Health Risk Assessment

5.1.1.1 Radiological Contaminants

For radiological emissions, individual dose to members of the critical group as the results of operation of all nuclear facilities at the Bruce nuclear site was less than 5 μSv/y, representing approximately 0.5 percent of the public dose limit. The dose to member of the critical group due to the operation of the WWMF is estimated to be less than 0.2 μSv/y, four orders of magnitude less than the public dose limit of 1000 μSv/y. Therefore, there are not considered to be any adverse radiological effects to the public due to operation of WWMF.

5.1.1.2 Non-Radiological Contaminants

Based on the screening level risk assessment, it is concluded that emissions of non-radiological substances resulting from the operations at the WWMF pose no adverse effects to human health. Further assessment of the impact of non-radiological contaminants on human health is not required.

5.1.1.3 Physical Stressors

Based on the results of field noise level measurements in 2014 from the Bruce nuclear site and the modelling results, it can be concluded the noise generated due to the operation of WWMF is acceptable and poses no adverse effects to human health.

5.1.2 Ecological Risk Assessment

5.1.2.1 Radiological Contaminants

The risk from radiological contaminants emitted from the WWMF was determined for indicator species across all trophic levels.

The total radiological dose received by each indicator species is below the benchmark values given in CSA N288.6-12 [2]. These doses are based on the maximum radionuclide concentrations at the WWMF for each medium and therefore represent the maximum dose the indicator species could receive from the existing environment at the WWMF. Therefore, radiological contaminants do not pose an adverse effect to biota at the WWMF. No further evaluation with respect to radiological contaminants is recommended.

5.1.2.2 Non-Radiological Contaminants

The risk from non-radiological contaminants emitted from the WWMF was determined for indicator species across all trophic levels.

No risks from non-radiological contaminants from the WWMF to terrestrial plants and invertebrates have been identified.

The risk to aquatic receptors (plants, invertebrates, fish, and amphibians) was determined for both surface water COPCs and sediment COPCs. There was no risk to aquatic receptors from any non-radiological contaminant in surface water.

Dioxins and furans in soil were found to present no risk to terrestrial birds and mammals. It was determined that non-radiological contaminants identified in surface water and sediment from the WWMF do not pose a risk to aquatic birds and mammals.

Risks to benthic invertebrates were also assessed for sediment COPCs based on the evaluation of two lines of evidence, including the comparison of sediment chemistry to the TRVs and a qualitative evaluation of benthic invertebrate field data. No adverse effects are likely as the result of non-radiological contaminant exposure with the exception of copper and zinc in sediment which has the potential for low to moderate risk to benthic invertebrates. Although the assessment for benthic invertebrate resulted in a HQ greater than one for copper and zinc (range of 1 to 1.6) in the SRD, no further monitoring is recommended considering the aquatic habitat is an industrial drainage ditch, and considering the following:

- Elevated levels of copper and zinc in the SRD can be attributed to a historic release from the SSTF (no longer operational) upstream of SRD-1, i.e., sediment copper and zinc concentrations at SRD-1 are not associated with the WWMF.
- In addition to the historic release from the SSTF, drainage culverts may be contributing to elevated zinc concentrations in the SRD. Aqueous zinc concentrations increased by up to a factor of five between sample locations WTL-1 and SRD-4, a distance of about 60 m, after flowing through two culverts, whereas sediment zinc concentrations increased by a factor of 3.5.
- It is difficult to distinguish whether the limited benthic community in the drainage ditch, which consists primarily of tolerant and facultative species, is strictly the product of the poor habitat quality the ditch provides or whether elevated sediment metal concentrations are having an effect. The ability to survive under low oxygen conditions during periods of low flow, or no flow (stagnation) is probably the dominant factor governing the benthic invertebrate community. The existing conditions are considered to meet the protection goal of maintaining a benthic invertebrate community that is characteristic of the on-Site industrial drainage system habitat.
- In the Wetland, downstream of the SRD, sediment concentrations were below the TRVs, and adverse impacts to the benthic invertebrate community are not anticipated.

Sediment chemistry in the West Ditch identified silver as exceeding the sediment TRV; however, a low potential for effects was identified based on the benthic invertebrate field data. It should be noted that the West Ditch is not located within the WWMF and the WWMF is not known to be a source of silver contamination to the West Ditch.

5.1.2.3 Physical Stressors

Quantitative analysis shows that the operation of the existing WWMF is unlikely to represent a noise disturbance beyond tolerance on species currently occurring within the vicinity of the WWMF. A qualitative assessment was performed to determine the risks that could result in road kill and bird strikes at the WWMF. No adverse effects were identified for either stressor; no further evaluation is required.

5.2 Recommendations

Based on the results of the assessment, there are no specific recommendations for the operation of the WWMF from the ERA perspective.

6.0 QUALITY ASSURANCE

The baseline ERA is conducted in accordance with the AMEC NSS Quality Assurance program [190]. The AMEC NSS Quality Assurance program is ISO 9001 registered and the scope of the ISO 9001:2000 registration covers "consulting to nuclear and other industries to support design and operations by providing specialized: software, integrated analytical and engineering solutions and services". The AMEC NSS Quality Assurance program has been audited by CANPAC and confirmed to meet the requirements of CSA Z299.1-85 [191] and the applicable sections of CSA N286-05 [192].

The main AMEC NSS Quality Procedures (NQP) applicable to this project include:

- NQP 6 – Work Planning and Execution;
- NQP 7 – Control of Documents;
- NQP 13 – Control of Records;
- NQP 32 – Software Development and Documentation; and,
- NQP 33 – Software Verification, Validation and Qualification.

Environmental data used to complete the baseline ERA was collected, analyzed, reported and managed, according to OPGs and Amec Foster Wheeler Nuclear Canada's Quality Assurance programs. The environmental data for the ERA was collected by qualified staff and analyzed by accredited laboratories. Samples were collected and analyzed in accordance with the management system requirements of CSA N286-05 [192]. The ERA also relied on data collected from Bruce Power's EMP ([23], [24], [25], [26], [27]). Public dose data was obtained from the Bruce Power EMP which maintains a QA/QC program for sample collection, analysis and data processing.

Additional data required to complete the ERA was collected under Amec Foster Wheeler Nuclear Canada's Quality Assurance Plan for Western Waste Management Facility Expansion Environmental Assessment Baseline Field Work which specifies the protocols and verification activities for the collection of the samples. The following Amec Foster Wheeler Nuclear Canada quality procedures were used in the collection of the data in addition to the procedures listed in the previous section:

- NQP 9 – Control of Non-Conforming Product;

- NQP 10 – Assessment of Suppliers;
- NQP 11 – Control of Preventative Actions;
- NQP 15 – Control of Project Procurement;
- NQP 22 – Project Closure; and,
- NQP 38 – Qualification, Use, Configuration Management, Change Control of Input Data Sets.

The analysis of the environmental data was completed by the Bruce Power Health Physics Lab, Kinectrics and Maxxam which are ISO 17025 [194] accredited laboratories. The Bruce Power Health Physics Lab operates a comprehensive QA program in accordance with ISO 17025 [194], which includes quality control samples, blank/background samples, process control samples and externally generated proficiency testing samples. The Kinectrics laboratory operates a comprehensive QA program which includes proficiency testing for C-14 analysis using a service provided by the National Research Council Canada. Kinectrics is accredited to ISO 17025 [194] by The Standards Council of Canada for radiochemical tests, including C-14 in water. Maxxam is accredited to ISO 17025 [194] for all the non-radiological analysis required for the work.

Following these Quality Assurance requirements, work was completed, reviewed and verified by qualified professional staff throughout the development of the baseline ERA.

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Appendix A: Acronyms and Glossary

ACRONYMS

AECL	Atomic Energy of Canada Ltd.
ALARA	as low as reasonably achievable, social and economic factors being taken into account
AO	Aesthetic Objective
APV	Aquatic Protection Values
ARCS	Assessment and Remediation of Contaminated Sediments
BAF	Bioaccumulation Factor
BEC	Bruce Energy Centre
BNGS-A	Bruce Nuclear Generating Station A
BNGS-B	Bruce Nuclear Generating Station B
BTAG	Biological Technical Assistance Group
CCME	Canadian Council of Ministers of the Environment
CEQG	Canadian Environmental Quality Guideline
CNSC	Canadian Nuclear Safety Commission
COPC	Contaminants of Potential Concern
CSA	Canadian Standards Association
CSL	Cleanup Screening Level
DGR	Deep Geologic Repository
DQRA	Detailed quantitative risk assessment
DRL	Derived Release Limit
DSC	Dry Storage Container
dw	Dry weight
EA	Environmental Assessment
EC10/20/25	Effective concentration where a prescribed percentage (10%, 20%, 25%, etc.) of the maximal effect is observed
ECA	Environmental Compliance Approval
EcoRA	Ecological Risk Assessment
ED20	Effective dose for 20% of the exposed population

EIS	Environmental Impact Statement
EMP	Environmental Monitoring Program
ESA	Endangered Species Act
EPT	Ephemeroptera Plecoptera Trichoptera
ERA	Environmental Risk Assessment
ER-L	Effect Range Low
ER-M	Effect Range Median
ESL	Ecological Screening Level
FCSAP	Federal Contaminated Sites Action Program
FPOM	Fine Particulate Organic Matter
fw	Fresh weight
HBI	Hilsenhoff Biotic Index
HC50	Hazardous Concentration for which for half of the species or processes are not protected
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
HTO	Tritium Oxide (tritiated water)
IC	In-ground Container (includes IC-18 and IC-HX)
ICRP	International Commission on Radiological Protection
ISQG	Interim Sediment Quality Guideline
L&ILW	Low and Intermediate Level Waste
LC10	Lethal concentration required to kill 10% of the population
LCV	Lowest Chronic Value
LEL	Lowest Effect Level
LLSB	Low Level Storage Building
LLW	Low Level Waste
LOAEL	Lowest Observed Adverse Effect Level
LOE	Line of Evidence
LOEC	Lowest Observed Effect Concentration
masl	Meters above sea level
MATC	Maximum acceptable toxicant concentration

MDL	Method Detection Limit
MNDM	Ministry of Northern Development and Mines
MOE	Ministry of Environment
MOECC	Ministry of Environment and Climate Change (formerly called MOEE)
MOEE	Ministry of Environment and Energy
MPA	Maximal Permissible Addition (for metals)
MSA	Middle Sand Aquifer
NC	Not calculated
NEC	No Effect Concentration
NOAEL	No Adverse Effect Level
NOEC	No Observed Effect Concentration
NV	No Value
OPG	Ontario Power Generation
PEC	Probable Effect Concentration
PEL	Probable Effect Level
PHC	Petroleum Hydrocarbon
PNEC	Predicted No Effect Concentration
POI	Point of Impingement
PQL	Practical Quantitation Limit
PQRA	Preliminary Quantitative Risk Assessment
PWQO	Provincial Water Quality Objectives
RAIS	Risk Assessment Information System
RATL	Database of reptile and amphibian toxicology literature
RCRA	Resource Conservation and Recovery Act
RCSB	Retube Component Storage Building
RDL	Reportable Detection Limit
SAR	Species at Risk
SCS	Site Condition Standards
SEL	Severe Effect Level
SEM-AVS	Simultaneously extracted metals/Acid-volatile sulphide

SGSB	Steam Generator Storage Building
SLC	Screening Level Concentration
SLRA	Screening Level Risk Assessment
SQG	Sediment Quality Guideline
SQS	Sediment Quality Standard
SQV	Sediment Quality Value
SRAeco	Serious Risk Addition for ecosystems (for metals)
SRD	South Railway Ditch
SSTF	Spent Solvent Treatment Facility
SWHTG	Significant Wildlife Habitat Technical Guide
TEC	Threshold Effect Concentration
TEL	Threshold Effect Level
TEQ	Toxic Equivalency Quotient
TF	Transfer Factor
TJF	Triple Joint Frequencies
TLD	Thermoluminescent Dosimeters
TPMB	Transportation Package Maintenance Building
TRV	Toxicity Reference Value
UCLM	Upper Confidence Limits on the Mean
US EPA	United States Environmental Protection Agency
VECs	Valued Ecosystem Components
VOCs	Volatile Organic Compounds
WOE	Weight of Evidence
WVRB	Waste Volume Reduction Building
ww	Wet weight
WWMF	Western Waste Management Facility

GLOSSARY

Assessment endpoints	For HHRAs, the assessment endpoint is no meaningful effect on human individuals. This endpoint is often described by regulatory limits and procedures. For EcoRA, the assessment endpoints are expressions of the environmental values to be protected. They are directly related to management goals but are usually stated in terms of the attributes, such as reproduction and population maintenance, of ecological receptors.
Conceptual model	Tools used to describe the relationship between contaminants and physical stressors and receptors. Focusing on the pathways through which exposure will occur, conceptual models could be the combination of graphics, figures, tables, maps and descriptive text.
Benchmark Value	A level of exposure below which meaningful effects are unlikely and above which there is a potential for meaningful effects. These values are often derived by evaluating lab studies, exposure investigations, epidemiological studies, and other sources of information.
COPC	Any contaminant that has been selected, based on the results of Tier one screening, for evaluation in higher tiers of assessment.
NOAEL	The level of exposure found by experiment or observation, at which there is no biologically or statistically significant increase in the frequency or severity of any adverse effects in the exposed population when compared to its appropriate control.
LOAEL	The lowest level of exposure found by experiment or observation that causes an adverse effect on a target organism distinguished from normal organisms of the same species under defined conditions of exposure.

Appendix B: Groundwater Environment at the WWMF

B.1 GROUNDWATER MONITORING AT THE WWMF

The potential risks to human and ecological receptors, associated with the groundwater environment at the WWMF, were assessed and documented in Section 3.3.6 and Section 4.3.2.2 of this report, respectively. In this Appendix, additional information with respect to the groundwater quality is discussed.

Groundwater monitoring has been carried out at the WWMF for over two decades. The purpose of the groundwater monitoring program is to observe and detect changes in groundwater quality that may occur as a result of WWMF operation. The locations of the groundwater monitoring wells at the WWMF are illustrated in Figure B-1. Both the shallower Middle Sand Aquifer (MSA) and the deeper bedrock aquifer are monitored. The MSA is generally localized to the WWMF and is separated from the underlying bedrock formation by a clay-rich silt till layer. However at discrete locations, the MSA directly overlies the bedrock and hydraulically connected to the bedrock aquifer. A recent geological and hydrogeological investigation has also determined a potential connection from the MSA to the south side of the railway ditch located north of the facility [B-1]. Radioactivity in the groundwater are routinely analysed at the WWMF and the results are reported quarterly to the CNSC.

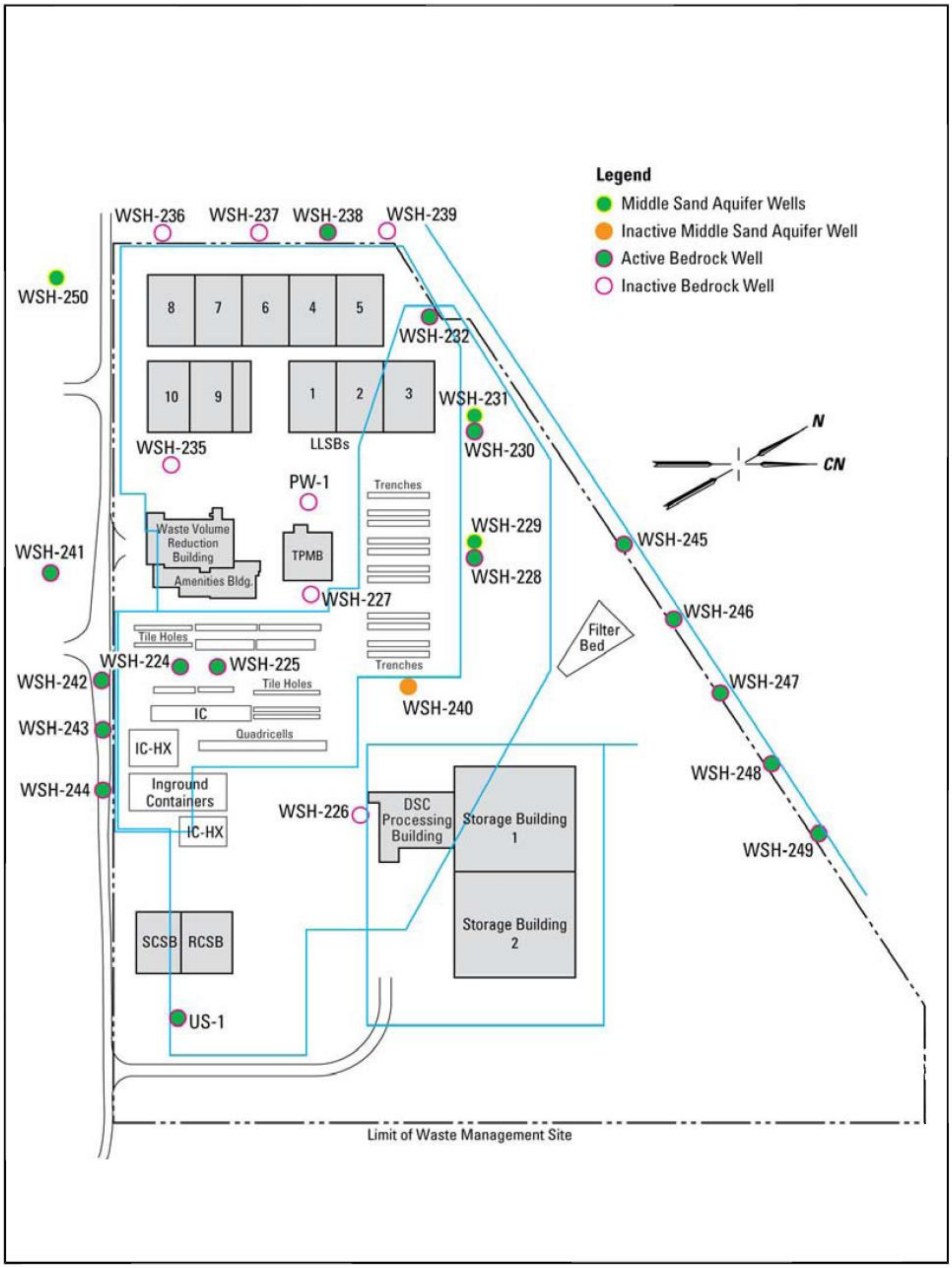
In addition to the WWMF groundwater monitoring program, additional baseline monitoring was carried out in 2014 in anticipation for future expansion of the site. The sampling program involved the collection of groundwater samples from seven groundwater wells, including up gradient and down gradient wells of the MSA and bedrock. The chemical components in groundwater at the WWMF were analysed to supplement the existing data set. Results for groundwater quality, such as volatile organic compounds, petroleum hydrocarbons, metals & inorganics, as shown in Appendix G, were consistent for all sampling rounds and below the screening criteria[24].

In recent years, elevated tritium levels have been observed in the MSA at well WSH-231 and immediate area (located directly down gradient of LLSBs 1-10) [B-2]. Specifically, tritium concentrations in well WSH-231 were detected at a maximum concentration of 8.0 E4 Bq/L in 2009, but has subsequently declined to a maximum of 5.6 E4 Bq/L in 2013, as shown in Table B-1[25]. However, the elevated tritium levels in MSA, which could discharge to bedrock, have negligible impact on the quality of groundwater flowing from the WWMF site. This is demonstrated with the tritium monitoring results of WSH-238 which is a representative down gradient bedrock aquifer well, as shown in Table B-2. In addition, the groundwater in the MSA could

[24] Orthophosphate concentration in one well is above the background level in Ontario. However, it was determined that it had no impact on surface water quality, on-site or off-site, as discussed in Section 4.3.2.2.

[25] There is no specific target or limit for radioactivity in groundwater at WWMF. However OPG has committed to notify CNSC if tritium levels at WSH 231 exceed 60,000 Bq/L [B-2].

also potentially discharge to the South Railway Ditch, which ultimately flows to Baie du Doré.



Note: Some buildings constructed in recent years including LLSBs #11-14 and UFDSBs #3-4 are not shown in this figure.

Figure B-1: Groundwater Monitoring Wells at the WWMF

Both of these pathways were reviewed and it was concluded that there was no impact to human and ecological receptors.

The latest investigation [B-1] provides strong evidence that an electrical manhole (Manhole #1) that is connected to LLSB#1 by conduits is the primary source of the tritium to the MSA [B-1]. OPG has taken remedial actions since February 2010 to reduce the source of the tritium by pumping down water in the LLSB electrical manhole. The contaminated water was pumped to a vacuum tanker and then transported to Bruce Power for disposal through the active liquid waste management system. WSH-231 is sampled and analysed bi-weekly, compared with the quarterly sampling frequency at other WWMF monitoring wells to increase surveillance of the elevated tritium at this location.

Table B-1: Tritium Concentrations in Well WSH-231 for the Period of 2009-2013

Year	Average (Bq/L)	Maximum (Bq/L)	Minimum (Bq/L)
2009	5.31E+04	8.00E+04	2.84E+04
2010	4.56E+04	6.59E+04	2.82E+04
2011	4.38E+04	7.49E+04	2.50E+04
2012	4.92E+04	6.75E+04	2.97E+04
2013	3.81E+04	5.63E+04	2.72E+04

Table B-2: Tritium Concentrations in Well WSH-238 for the Period of 2009-2013

Year	Average (Bq/L)	Maximum (Bq/L)	Minimum (Bq/L)
2009	1.27E+01	1.34E+01	1.18E+01
2010	1.08E+01	1.16E+01	1.01E+01
2011	1.09E+01	1.15E+01	1.02E+01
2012	1.07E+01	1.17E+01	9.75E+00
2013	1.04E+01	1.11E+01	9.30E+00

A source term assessment and groundwater monitoring network design enhancement is currently being completed at the WWMF. The work involves identifying potential source terms that may influence groundwater quality and determining if there is sufficient information to assess these potential impacts. This assessment is to identify areas where the understanding of the geological and hydrogeological environment could be improved and, as a result, additional groundwater monitoring wells have been installed. After the program is completed the data collected will be used to refine the WWMF groundwater monitoring program.

B.2 REFERENCES

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[B-2] OPG, Nuclear Waste Management Division Western Waste Quarterly Operations Report 2014, Fourth Quarter 2013, W-REP-00531.1-00070.

Appendix C: Ecological Profiles for Indicator Species

See Appendix D for receptor characteristics.

C.1 AQUATIC RECEPTORS

C.1.1 Cattail

Physical Appearance

The Common Cattail (*Typha latifolia*) is a large perennial aquatic plant which grows in dense monocultures. Cattails have thick, linear leaves with a large, cylindrical distinctive spike of flowers near the top of the stalk. They can grow up to 2 m in height [C-1].

Habitat

Cattails commonly occur in freshwater wetlands. However, disrupted aquatic ecosystems can favour cattail growth, and they have been known to grow in varied environments including roadside ditches, reservoirs, and estuaries [C-1].

Reproduction

Cattails are unisexual, wild pollinated weeds. The female flowers form the brown cylinder near the top of the stalk, while the male flowers are located above this cylinder [C-1].

Economic and Other Importance

Cattails, though a native species, behave like aggressive introduced weeds. They are commonly considered a nuisance plant and can be difficult to control [C-1].

C.1.2 Digger Crayfish

The Digger Crayfish (*Fallicambarus fodiens*) has been recorded on site at the WWMF [C-2].

Physical Appearance and Body Mass

The digger crayfish is a medium-sized crayfish. It is brown to olive with darker mottling. The abdomen has a striped appearance with a pale centre line glanced by darker pigment. There are two rows of tubercles along the mesial margin of the palm and areola is obliterated. The rostrum is fairly broad and tapering and has no marginal spines or tubercles. The total body length is approximately 75 mm [C-3].

Habitat

The Digger Crayfish is an obligate burrowing, semi-terrestrial crayfish. It creates complex burrows adjacent to streams and seepage areas, or in low areas where the water table is near to the surface. In the spring, they can be found in open water, such as streams or ditches [C-3].

Diet

The diet consists of a variety of plant and animal materials [C-3].

C.1.3 Northern Redbelly Dace

Physical Appearance and Body Mass

Northern Redbelly Dace (*Chrosomus eos*) are a common freshwater minnow [C-4]. They are typically between 3.1 and 6.8 cm in length [C-5]. They are olive to dark brown, with a belly that is usually yellow or silver except during the mating season, when on males the belly will turn red [C-4].

Habitat

Northern Redbelly Dace prefer cool water, lacustrine or riverine habitats. They can be found in lakes, bogs, ponds and pools with aquatic vegetation [C-5].

Diet

Northern Redbelly Dace primarily consume benthic invertebrates [C-5]. They have been recorded consuming algae [C-4].

Reproduction

Northern Redbelly Dace spawn in the spring and summer, typically between May and July [C-5].

C.1.4 Spottail Shiner

Physical Appearance and Body Mass

Spottail Shiner (*Notropis hudsonius*) are a freshwater minnow. They are typically between 5.8 cm and 12.7 cm in length, and 0.001-0.016 kg in weight [C-6]. Spottail Shiners have a black spot at the base of the tail. They can be silvery to pale green or olive in colour on the back [C-7].

Habitat

Spottail Shiner prefer cool water, and generally live in lacustrine or riverine habitats. It inhabits a benthopelagic, shoreline environment. They can be found in lakes, rivers, and streams [C-6].

Diet

Spottail shiner primarily consume invertebrates, including aquatic insect larvae, and plankton ([C-6], [C-7]). They also consume algae [C-7].

Reproduction

Spottail Shiners spawn in the spring, typically between May and June, in lacustrine and riverine environments [C-6].

Economic and Other Importance

Spottial Shiners are used as forage and bait fish. They are widespread throughout Ontario [C-6].

C.1.5 Smallmouth Bass

Physical Appearance and Body Mass

The Smallmouth Bass (*Micropterus dolomieu*) is a member of the sunfish family. They have two dorsal fins that appear to be joined, the front of which has spines and the back which has rays. They have a streamlined body shape and are 20-38 cm in length. The upper jaw of the Smallmouth Bass reaches to near the rear margin of the eye. They have irregular dark brown vertical dorsal bars. The overall body colour can vary from a dark-brown to a greenish-brown to bronze, with a cream or white underside [C-8].

Habitat

Smallmouth Bass are a lake fish, though they can also inhabit rivers. They typically require large lakes or wide rivers. They are generally considered to be a cool water fish, though they are relatively tolerant of high water temperatures. They will seek out structures such as logs, rocky outcroppings, or pier posts [C-8].

Diet

Adult Smallmouth Bass consume primarily fish, insects and crayfish. Young Smallmouth Bass will consume zooplankton, but shift to aquatic insects and gradually fish as they grow [C-8].

Reproduction

Smallmouth Bass spawn as late as June or July in rocky shoals. Eggs hatch 4-10 days after being laid [C-8].

Economic and Other Importance

Smallmouth Bass are an important recreational sportfish, and are one of the most popular sportfish in North America. However, they will spread invasively to new water bodies and supplant the native fish species [C-8].

C.1.6 Lake Whitefish

Physical Appearance and Body Mass

The Lake Whitefish (*Coregonus clupeaformis*) is a freshwater fish that is elongate in form, with a small mouth. They are a silver colour overall, with clear or lightly coloured fins. The mean fork length for Lake Whitefish is approximately 56 cm, and the mean weight is approximately 2100 g [C-9].

Habitat

Lake Whitefish are a freshwater fish that prefer cold water. They spend most of the year in deep water areas of lakes, moving to shallower water in the early spring and in fall [C-9].

Diet

Lake Whitefish primarily eat benthic invertebrates, including insect larvae, molluscs, and amphipods. Young fish will also consume plankton [C-9].

Reproduction

Lake Whitefish spawn in the fall and early winter, from November to December in the Great Lake, in shoals made of boulder, cobble, and gravel. Eggs are deposited randomly and settle between shoals. The eggs hatch in April or in May [C-9].

Economic and Other Importance

Lake Whitefish are an important commercial species in Canada. The Lake Huron population is important for the First Nations commercial fishery [C-10].

C.1.7 Deepwater Sculpin

Physical Appearance and Body Mass

The Deepwater Sculpin (*Myoxocephalus thompsoni*) is a lake-dwelling sculpin with a flat, long body averaging 47.2-110.5 mm in total length (average 76.7 mm). It has eyes on the top of its head and a large mouth with small teeth on both jaws, tongue, and roof of mouth. It is dark grey to brown in colour with dark saddles marking the back, light specking on the sides, and a pale belly, and lacks true scales. It has separated dorsal fins, large pectoral fins, reduced pelvic fins, a long base on the anal fin, and a square or truncated caudal fin. The pectoral fins have three dark bands on them. The pelvic fins are lightly spotted, and the dorsal and anal fins are faintly blotchy [C-11].

Habitat

The deepwater sculpin inhabits deep, cold lakes in areas that were formerly glaciated. It is bottom-dwelling and can be found in cold (<7°C), well oxygenated, deep lakes. In the Great Lakes, adults generally live between 60-150 m in depth [C-11].

Diet

The diet of the deepwater sculpin consists primarily of *Mysis relicta*, *Dipoeria* spp., and chironomid larvae. Secondary food items can include trichopteran larvae, sphaeriid clams, ostracods, leeches, fish eggs, and small fishes [C-11].

C.2 TERRESTRIAL VEGETATION

C.2.1 Grass

A common grass found on the WWMF and vicinity is Reed-canary Grass (*Phalaris arundinacea*).

Physical Appearance

It is a rhizomatous perennial grass, which grows from 0.9 – 1.8 m in height. The stems are sturdy and often hollow with some red colouring near the top, and can be up to 1.3 cm in diameter. The leaf blades are flat and hairless, 0.64 to 1.9 cm wide. The flowers are borne in panicles on culms high above the leaves. The panicles are generally 7.6 to 15.25 cm in length [C-12].

Habitat

Reed-canary grass typically occurs in soil which are saturated or nearly saturated for most of the growing season, but where standing water does not persist for extended periods [C-12].

Reproduction

Reed-canary grass is a perennial species. This species flowers in June and July [C-12].

Economic and Other Importance

Reed-canary grass forms dense, highly productive single species stands that pose a threat to wetland ecosystems. They are able to inhibit and eliminate competing species [C-12].

C.2.2 Eastern White Cedar

Physical Appearance

The Eastern White Cedar (*Thuja occidentalis*) is a member of the pine family of trees, which consists of over 200 species. These trees have a tapering trunk surrounded by a sheath of bark that supports branches that carry a crown of narrow leaves. They are approximately 10 m tall, and weigh approximately 471 kg. The trees have both male and female flowers. Reproduction results in woody female cones with spirally arranged scales [C-13].

Habitat

The eastern white cedar is common in temperate regions. It requires nutrient-rich soils for growth. The main elements it requires are nitrogen and phosphorus; however, trees also require potassium, sulphur, magnesium and calcium, with small quantities of other elements such as iron and zinc [C-13].

Diet

The root system of the eastern white cedar consists of a taproot and branch roots which anchor the stem and obtain water and minerals from the soil through the root hairs. Chlorophyll in the leaves absorbs energy from daylight which is used to photosynthesize carbohydrates, starch, and cellulose from water and carbon dioxide. Energy is obtained from the oxidation of carbohydrates [C-13].

Reproduction

The eastern white cedar has separate male and female flowers borne in separate strobili. Pollination occurs from tree to tree by wind. After pollination, the male flowers are shed and the female flowers grow into large pine cones with fertilized seeds [C-13].

C.3 TERRESTRIAL INVERTEBRATES

C.3.1 Earthworm

Physical Appearance and Body Mass

The common earthworm (*Lumbricus terrestris*) is member of the class Oligochaeta. There are approximately 3000 members of this class worldwide. This class is characterised as segmented worms with a visceral, fluid-filled cavity (the coelom) which acts as a hydrostatic skeleton and is surrounded by a muscular wall with an arrangement of circular and longitudinal muscles. This internal arrangement allows the worms to shorten or lengthen their bodies and coil themselves into shapes. An adult earthworm is approximately 5.24×10^{-3} kg in weight, with a length of 10 cm [C-13].

Habitat

Earthworms are terrestrial invertebrates that occur in a variety of habitats all over the world. However, they spend the majority of their time in the soil and therefore are found rarely in deserts, areas under constant snow and ice, and areas lacking in soil and vegetation [C-13].

Diet

Earthworms use a variety of organic materials for food, including plant material, decaying organic animal matter, or, if necessary, soil itself [C-13].

Reproduction and Social Behaviour

Earthworms are hermaphroditic, but not self-fertilizing. They reproduce by cross-fertilisation with another member of the species. They are generally continuous breeders. Breeding worms will produce capsules containing the fertilised eggs; the number of capsules produced and the time of hatching from the capsule is related to soil temperature [C-13].

C.3.2 Bee

Physical Appearance and Body Mass

Bees (family Apidae) are insects with membranous wings, a stinger, and long tongues to gather pollen. They weigh approximately 5.89×10^{-4} kg, and are approximately 2 cm in length [C-13]. Colouration is variable in the abdomen; it varies between brown and yellow on the T1 and T2 segments, while remaining segments are completely black [C-14].

There are at least 25,000 bee species around the world, with 4,000 known in North America. The family Apidae are the most widely studied family, consisting of the bumblebee and the honeybee [C-13].

Habitat

Specific bee habitat varies between species of bee, though generally they require a temperate climate. Bee habitat varies by species, but they can exist anywhere there is vegetation on the ground.

Bees from the family Apidae normally form their nests in dry caves or hollow trees, though "domesticated" colonies also live in beehives. A principal feature of the nest is the honeycomb, a thin sheet of wax covered with hexagonal cells. The nests typically contain a brood chamber housing the queen and the larvae, and a surrounding chamber used to store honey and pollen.

Temperatures inside the nest are highly controlled; honey bee larvae are likely to die at temperatures below 32°C or above 36°C [C-13].

Diet

Worker bees collect pollen and nectar for feeding; larvae are fed pollen and nectar directly. Adult bees form honey from the nectar. Some of the honey formed is retained as food for the workers, while the rest is stored as food for the winter with the pollen [C-13].

Reproduction and Social Behaviour

Bees in the family Apidae are highly social and live in colonies that are essentially an enormous single-family unit. These colonies consist of a single egg-laying female (the queen), plus sterile daughters (the workers), and male drones. The female workers are reared from fertilized eggs. Male drones are only occasionally reared as needed, and they are produced from unfertilized eggs through a process known as "parthenogenesis".

Workers behave cooperatively to gather food for the colony, build the nest and rear the young. There may be up to 80,000 worker bees at any one time per colony [C-13].

Economic and Other Importance

Bees are an important pollinator of many industrial crops and native flowering plants. They are important to many species of mammals, birds, and other organisms while rely on pollinated plants for food and shelter [C-14].

A number of species of bee have suffered severe population declines and are now considered SARs. The Rusty-patched bumble bee is listed on the Species at Risk in Ontario list [C-15] and SARA Schedule 1 [C-16] as Endangered. SARA Schedule 1 also includes other species of bees whose ranges include Ontario: the Gypsy Cuckoo bumble bee (endangered) and the Yellow-banded bumble bee (special concern) [C-16].

C.4 HERPETOFAUNA

C.4.1 Northern Leopard Frog

Physical Appearance and Body Mass

The Northern Leopard Frog (*Rana pipiens*) is a true frog species. They are medium-sized, approximately 5-9 cm in length, and are strongly spotted. They generally weigh between 30 and 70 g [C-17].

The frog's skin absorbs water and gas exchange occurs across the skin. Adult frogs frequently shed the outer layer of skin. Skin casts are eaten following molting [C-13].

Habitat

Adult frogs are truly amphibious, living at the edge of water bodies and entering the water to catch prey, flee danger, and spawn. They are found near shallow freshwater, and live at the margins of permanent or semi-permanent shallow water, springs, swamps, streams, ponds and lakes. The frogs inhabit aquatic habitats approximately two thirds of the time, primarily for refuge and temperature regulation. The one third of the time spent in terrestrial habitats is primarily for feeding [C-17].

Diet

Adult frogs are carnivorous, eating a wide variety of small invertebrates and even vertebrates [C-13]. They will consume insects, worms, small fish, crayfish, other crustaceans, newts, spiders, small frogs, and molluscs. Their main food source is insects which are locally abundant along the shoreline, primarily beetles [C-17].

Tadpoles feed by grazing on algal material and bacteria [C-13].

Temperature and Hibernation

The physiological processes of the frog are temperature dependant. In cold areas, frogs will hibernate [C-13]. Hibernation occurs underground or underwater from fall to spring. In the water, frogs will hibernate in the mud and debris at the bottom of streams. The will begin to emerge when the mean daily temperature is approximately 4.4°C [C-17].

Reproduction and Social Behaviour

Frogs breed from spring through summer, spawning primarily at night [C-17]. Female frogs will lay their egg masses in water, and the male frog will immediately fertilise them [C-13]. The eggs typically hatch within 3-6 days [C-17] into aquatic larvae (tadpoles) that will metamorphose into terrestrial adults [C-13].

C.4.2 Spring Peeper

Physical Appearance and Body Mass

The Spring Peeper (*Pseudacris crucifer*) is a small treefrog, approximately 2.5 cm in length. Spring peepers vary in colour from a dull gray or tan to a bright red or a pink. Spring peepers have a distinctive "X" on the dorsum [C-18].

Habitat

Spring peepers are a terrestrial, freshwater frog that is found in moist wooded areas [C-19], such as forests and regenerating woodland. The terrestrial habitat must be located near ephemeral or semi-permanent wetlands for breeding [C-18]. When inactive, spring peepers hide under logs, rocks, or other objects [C-19].

Diet

Adult spring peepers will consume insects, worms, and spiders. They are carnivorous; their main food source is insects [C-17]. Tadpoles feed by grazing on aquatic plant material [C-13].

Temperature and Hibernation

Spring peepers, in the northern reaches of their distribution, endure occasional periods of subfreezing temperatures. They are tolerant of freezing of some bodily fluids [C-18].

Reproduction and Social Behaviour

Spring peepers breed in aggregations of several hundred individuals. They breed in small wetlands, such as swamps, temporary pools and disturbed habitats such as farm ponds [C-18]. Eggs are laid and larvae develop in small temporary or permanent ponds, especially those with standing plants or debris [C-19].

C.4.3 Painted Turtle

Physical Appearance and Body Mass

The Midland Painted Turtle (*Chrysemys picta marginata*) has an olive to black carapace (upper shell) with red or dark orange markings on the marginal scutes (enlarge scales), as well as red and yellow stripes on the head and neck. The carapace is broad, smooth and flat. The lower shell (plastron) is yellow or dark tan, with an irregular dark butterfly-shaped marking along the midline [C-20]. Painted turtles are sexually dimorphic, with the female larger than the male. Painted turtles are a medium-sized turtle, averaging 11.5 – 14 cm in size, with the female 260-330 g and the smaller male 170-190 g [C-17].

Habitat

Painted turtles are primarily aquatic turtles; their habitats require shallow water features with soft and muddy bottoms, basking sites, and floating aquatic vegetation for feeding and cover. They can commonly be found in ponds, marshes, and ditches [C-17].

Diet

Painted turtles are omnivorous, and may consume either primarily vegetation or primarily animal matter; the ratio depends on the turtle’s age and habitat, but juveniles have been shown to consume a larger amount of animal matter while adults eat a larger amount of vegetation. The animal component of the turtle’s diet tends to be dominated by insect larvae, while algae is a dominating plant component [C-17].

Temperature and Hibernation

The turtles are diurnal; they forage in the late morning and late afternoon, bask during the day, and spend their nights sleeping submerged. They are mostly dormant during the colder months, hibernating in the mud at the bottom of ponds; they become active during warms periods in the winter [C-17].

Reproduction and Social Behaviour

Painted turtles mate in the spring and summer and lay their eggs in high banks [C-17].

C.4.4 Northern Water Snake

Physical Appearance and Body Mass

The Northern Water Snake (*Nerodia sipedon*) is brown with faint horizontal banding [C-21]. Adults are typically 61-107 cm in length [C-17].

Habitat

The Northern Water Snake is largely aquatic, preferring streams to other water bodies, though it can be found in lakes and ponds, as well as riparian areas. They are absent from water bodies with soft muddy bottoms as these may interfere with their foraging [C-17].

Diet

Northern water snakes are carnivorous, consuming primarily fish and amphibians, but also occasionally insects and small mammals [C-17].

Temperature and Hibernation

Northern water snakes are active both during the day and at night, but mostly between 21 and 27 C. During the day, they can be found near basking sites. The snakes winter in nearby rock crevices or banks [C-17].

Reproduction and Social Behaviour

Northern water snakes breed primarily in the early spring [C-17].

C.5 BIRDS

C.5.1 Wild Turkey

Physical Appearance and Body Mass

The wild turkey (*Meleagris gallopavo*) is a large bird that is brown to grey in colour, with iridescent black and green barring. It has a small, unfeathered head, the flesh of which is blue and red on the male turkey [C-22]. The wild turkey has a body length of 1.1-1.2 m, a wingspan of 1.3-1.4 m, and a weight range of 2.5-10.8 kg [C-23].

Habitat

The natural habitat of the wild turkey is the deciduous forest, however it has been shown that they can adapt to a range of landscape-level habitat conditions, including agricultural landscape and are now considered deciduous forest habitat generalists. The most specific habitat requirement for the wild turkey is brood cover; hens will nest in a variety of forest and open habitats with adequate cover at the nest site. This allows turkeys to use forest, savannah, and prairie habitats [C-24].

Diet

Adult turkeys consume primarily mast, such as acorns and seeds. Their natural diet also includes fruits, green vegetation and insects. Turkeys may also feed on domestic grains, forages, and berries. Young turkeys feed almost exclusively on insects, while adults will consume insects in proportion with their availability [C-24].

Reproduction and Social Behaviour

Wild turkeys are promiscuous breeders, with individual adult males mating with multiple females. A single mating is capable of fertilizing an entire egg clutch [C-24].

Economic and Other Importance

Wild turkeys had been nearly extirpated in Ontario but management efforts have successfully reintroduced them to the province. They are now important for hunting and occasionally an agricultural pest species [C-24].

C.5.2 Red-Eyed Vireo

Physical Appearance and Body Mass

The Red-eyed vireo (*Vireo olivaceus*) is a small songbird, weighing an average of 17 g [C-25]. The Red-eyed vireo has an average size of 15 cm [C-26]. Their feathers are olive-green, with a yellow and white breast. They have a blue-gray crown, bordered by three stripes [C-27].

Habitat and Migration

The preferred habitat of the red-eyed vireo is the deciduous woodland, preferring to feed in areas with an abundant canopy and a moderate to dense understory. The red-eyed vireo is migratory, and during autumn migration they also utilize low edge vegetation habitat [C-25].

Diet

The red-eyed vireo is primarily insectivorous, with animal matter making up approximately 85% of the diet. Insects are generally hunted through gleaning, though hovering, hawking, and pecking are also occasionally used. The diet is primarily made up of insects and some spiders during the breeding season; late in summer and in fall berries and fruit are eaten more frequently [C-25].

Reproduction and Social Behaviour

Red-eyed vireos build their nests approximately 10 ft. above ground in the form of a small tree. Three to five eggs may be laid. The female bird is solely responsible for incubation of the eggs, but the male bird will help with the brooding and feeding of young [C-25].

C.5.3 American Robin

Physical Appearance and Body Mass

The American robin (*Turdus migratorius*) is a common, medium-sized songbird that averages 25 cm from tail-to-tip. There is little variation between the sexes in terms of size [C-17]. The average weight of the American robin is 79 g [C-28]. They have a distinctive rust-orange coloured breast and a dark gray-brown back, with a yellow beak [C-29].

Habitat and Migration

The American robin can live in a variety of habitats, including woodlands, swamps, suburbs, and parkland. They require access to freshwater, protected nesting sites, and productive foraging areas for their habitats. Breeding habitat includes moist forests, swamps, open woodlands, orchards, parks and lawns. They will form their nests out of mud and vegetation near the edges of a forest or other opening in vegetation, on horizontal branches, within shrubs, or on man-made structures with horizontal surfaces. The American robin is migratory, breeding in northern latitudes and wintering in the south [C-17].

Diet

The diet of the American robin is made up of earthworms, insects, and fruit. The American robin forages on the ground in open areas, along habitat edges or streams by probing and gleaning; they also forage above ground in shrubs or in lower tree branches. The robin forages for ground-dwelling invertebrates on the ground, and in shrubs and lower tree branches for fruit and foliage-dwelling insects. During the breeding season the American robin eats primarily invertebrates with some fruit; the rest of the year the robin’s diet is primarily made up of fruit [C-17].

Reproduction and Social Behaviour

Mating and egg laying for the American robin generally occurs in April or May. Females will pair with males that have established territories at the breeding site for the duration of the breeding season. First clutches generally contain three or four eggs; later clutches will contain fewer eggs. The female robin does all of the incubating, while both the male and the female feed the nestlings [C-17].

C.5.4 Mallard

Physical Appearance and Body Mass

The Mallard (*Anas platyrhnchos*) is a dabbling suck with a brightly coloured patch of feathers on the trailing edge of each wing. They are sexually dimorphic; the plumage of the male ducks is more colourful than the plumage of the females. They average 50 cm in length from the tips of their bills to the ends of their tails [C-17]. The average weight of the mallard is 1.2 kg [C-28].

Habitat and Migration

Mallards prefer wetlands and rivers as habitat; they prefer a water depth of 20 to 40 cm for foraging. Nesting habitat is dense grassy vegetation of at least half a meter in height; mallards prefer habitat with concealment from predators. Nests are usually located within a few kilometers of water. Mallards are migratory; they tend to arrive at their wintering grounds in the south between mid-September and early November and depart for their breeding grounds in the north in March [C-17].

Diet

The mallard is a surface-feeding, dabbling duck that feeds in shallow water. They feed primarily on aquatic plants, seeds and aquatic invertebrates. In winter, they feed primarily on seeds, and also on invertebrates. Laying females consume a larger amount of animal matter than males or non-laying females, whose diet is primarily herbivorous. Ducklings have a diet made up almost exclusively of animal matter [C-17].

Reproduction and Social Behaviour

Mallards generally lay first clutches by late April or May. However, high rates of nest failure require female mallards to re-nest persistently to obtain a successful nest. Initial clutch size is larger than later clutches, so re-nesting females have smaller clutches. Older females produce larger clutches than yearlings. Males leave females at the onset of incubation, while females remain with the brood until fledging. Mallards are serially monogamous and will re-mate every year [C-17].

C.5.5 Bald Eagle

Physical Appearance and Body Mass

The Bald Eagle (*Haliaeetus leucocephalus*) is a large bird of prey with pale eyes; yellow bills; white heads, necks and tails; and dark brown bodies. Young eagles are a mixture of brown and white, with a black bill in young birds [C-30]. Bald eagles have long rounded wings, a large hooked bill, and sharp talons. Bald eagles are sexually dimorphic; females are significantly larger than males, but otherwise they look alike [C-17]. The female Bald Eagle is slightly larger than the male; their bodies are 79-94 cm long, with a wingspan of 178-229 cm [C-30]. The average body weight of the bald eagle is 4.7 kg; the male typically weights 3.7-4.9 kg and the female 4.6-6.4 kg [C-28].

Habitat and Migration

Bald Eagles are found throughout North America; they nest in a variety of habitats and forest types [C-30]. Their habitats are usually restricted to coastal areas, lakes, or rivers; they prefer mature trees with large, open crowns and stout limbs for perching or roosting. Bald eagles are migratory under certain conditions; they will migrate from areas where the water bodies become completely frozen over in winter, but will remain as far north as open water and a reliable food supply allow [C-17]. The nests are nearly always near a major lake or river where most of their hunting is done [C-30]; they prefer to build their nests in large trees with sturdy branches, but they will also nest in rocky outcrops. A distance from human disturbance is vital for nest site selection; nests have been reported to fail as a result of disturbance [C-17].

Diet

Bald eagles are primarily carrion feeders. They will eat dead or dying fish when available, but will also catch live fish near the surface of water. Bald eagles are opportunistic feeders, and will eat birds, mammals, or whatever is available [C-17]. While fish are their main source of food, Bald eagles can easily catch prey up to the size of ducks [C-30]. Bald eagles will forage in upland areas in winter when surface waters are frozen [C-17].

Reproduction and Social Behaviour

Bald eagle mating and egg laying occur in the spring. Both the male and female take responsibility for feeding the young. Young eagles fledge at 10 – 12 weeks; however, after leaving the nest they are still dependant on their parents for several weeks and will often return for food. Breeding pairs of bald eagles remain together as long as both are alive [C-17].

Economic and Other Importance

Since they scavenge for carrion, Bald eagles are particularly vulnerable to environmental contaminants or pesticides. They are also very susceptible to biomagnifications through the food chain as they are a higher trophic level predator [C-17]. The Bald Eagle is listed on the Species at Risk in Ontario List with a status of "Special Concern" [C-30].

C.6 MAMMALS

C.6.1 Muskrat

Physical Appearance and Body Mass

The Muskrat (*Ondatra zibethicus*) is a primarily aquatic rodent [C-17]. Muskrats are 25-36 cm long from the head to the end of the body, with a 20-25 cm long tail. Adult muskrats weight from 0.5 kg to over 2 kg [C-17]; 1 kg is the average weight [C-28]. The muskrat has a long, laterally flattened tail and webbed hind feet [C-10].

Habitat

Muskrats spend most of their lives in or near bogs, marshes, marshes, lakes, streams, ponds or creeks. Muskrats will either excavate dens in the banks of shores or will construct lodges from plant materials; however, dens are preferred. In the winter, muskrats will construct pushups to minimize their exposure to cold water. These pushups are cavities formed in piles of vegetation which have been pushed up through holes in the ice in a marsh. Muskrats will change their home range in response to water levels; however, only a portion of drought-evicted muskrats can usually find a new home [C-17].

Diet

Muskrats are primarily herbivorous, with a diet of mainly aquatic vegetation. Important foods for the muskrat are marsh grasses and sedges, as well as cattails [C-10]; where cattail is plentiful, it can make up as much as 80% of the muskrat's diet [C-28]. While the muskrat primarily eats the roots and basal portions of plants, it will also eat the shoots, bulbs, tubers, stems, and leaves.

Muskrats tend to forage near their lodges or dens; they rarely stray further than 5 or 10 m from them for foraging. They will sometimes dig for food on lake or pond bottoms. When muskrats eat animals, they will eat crayfish, fish, frogs, turtles, or young birds [C-17].

Reproduction and Social Behaviour

Muskrats are solitary or form breeding pairs; other pairs are excluded from their home range. Breeding occurs in spring and summer, with the first litters born in late April or early May [C-17].

Economic and Other Importance

Muskrats represent one of the most valuable fur animals in North America [C-17].

C.6.2 Northern Short-tailed Shrew

Physical Appearance and Body Mass

The Northern short-tailed shrew (*Blarina brevicauda*) are small mammals, generally 8 – 10 cm in length with a 1.9 – 3 cm long tail. Some Northern short-tailed shrews weigh over 22 g [C-17].

Habitat

The Northern short-tailed shrew can inhabit a wide variety of habitats; it is common in areas with abundant vegetation cover. The shrew requires cool, moist habitats due to their high metabolic and water-loss rates. They inhabit round, underground nests and maintain underground runaways which are usually 10 cm below the soil surface, but can be as deep as 50 cm [C-17].

Diet

The Northern short-tailed shrew is carnivorous, eating primarily invertebrates such as insects, earthworms and snails; however they may also eat plants, fungi, millipedes, centipedes, arachnids, and vertebrates such as mice, voles, and frogs. Small mammals are typically only consumed when invertebrates are less available. They are able to consume other small mammals due to a poison in the salivary glands that is transmitted during biting. Since they eat other vertebrates, shrews can concentrate DDT and other bioaccumulative chemicals to high levels.

The Northern short-tailed shrew has a high metabolic rate, and is able to eat its body weight in food each day.

The Northern short-tailed shrew stores food in the autumn and winter [C-17].

Reproduction and Social Behaviour

The northern short-tailed shrew likely breeds all year, with limited breeding occurring in the winter. Peak breeding occurs in the spring and late summer or early fall [C-17].

C.6.3 Little Brown Bat

Physical Appearance and Body Mass

The little brown myotis (*Myotis lucifugus*) are a small, plain-nosed bat. Their average weight is 7.9 g, with a typical range of 5.5 – 11.0 g, and a wingspan of 22 – 27 cm. They are brown-pelaged, and the tragus is short and blunt [C-31].

Habitat

The habitat required by the little brown myotis includes hibernacula for overwinter survival and summering areas with suitable foraging areas within commuting range to structures used for roosting or maternity colonies. In the summer, little brown myotis will use a variety of structures as day-roosts, including buildings, bridges, rock crevices, behind flaking bark, and within tree cavities. Females will establish maternity colonies in warm sites, such as attics of buildings, under bridges, in rock crevices, or cavities of canopy trees in forests.

Little brown myotis overwinter in cold and humid hibernacula, such as caves and mines [C-31].

Diet

Little brown myotis are insectivorous, consuming 4 – 8 g of insects per night. Foraging occurs over water, along waterways, on forest edges and in gaps in the forest. Large open fields or clear-cuts are generally avoided [C-31].

Reproduction and Social Behaviour

Mating occurs during the late summer/autumn swarming periods. Bats will mate upon return to the hibernacula, then enter the hibernacula to overwinter. The female bat will ovulate in the spring, and, upon leaving the hibernacula, will establish a summer maternity colony. Females typically produce one pup [C-31].

Economic and Other Importance

Little brown bats are listed on the Species at Risk in Ontario list [C-32] and SARA Schedule 1 [C-16] with a status of Endangered. They are facing imminent extinction or extirpation in Ontario. They are threatened by a disease known as white nose syndrome, which is caused by a fungus that disrupts their hibernation cycle, causing them to use body fat supplies before the spring. Bats at more than three quarters of Ontario's hibernation sites are at high risk of disappearing [C-32].

C.6.4 White-Tailed Deer

Physical Appearance and Body Mass

The White-Tailed Deer (*Odocoileus virginianus*) is a large mammal with an average weight of 80 kg, length of 89 cm and height of 41 cm [C-33]. They are sexually dimorphic; the males are typically larger than the females with average weights of 91 kg and 60 kg, respectively [C-28]. They are slim and long-legged [C-13].

The colour and texture of the white-tailed deer's coat changes seasonally. It is short and stiff in the summer, with a red colour similar to the red fox. In the fall, their coats change to grey and become longer and thicker to hold in warmth. The male deer grows and sheds antlers each year [C-10].

Habitat

The general habitat of the white-tailed deer is forest. They prefer woodlands, meadows, valleys, stream courses and rolling country [C-28]. The habitat of the white-tailed deer must offer a variety of vegetation, including a mixture of open and wooded areas. White-tailed deer thrive in disturbed forests [C-10].

In the winter, deer yards provide protection from the cold and deep snow. These areas include white cedar swamplands or dense stands of hemlock, jack pine or other upland conifers which block snow and reduce heat loss [C-10].

Diet

The white-tailed deer is an herbivore, which obtains food by browsing. Its diet is seasonally variable; in the winter, they prefer the buds and twigs of shrubs. In the fall, they prefer fruit and mushrooms, and in the summer they prefer grasses and herbaceous plants. Eastern white cedar is a major component of the diet of the white-tailed deer [C-28].

Reproduction and Social Behaviour

White-tailed deer are autumn breeders, with the season peaking in early November [C-28]. Usually one or two fawns are born [C-16].

Deer live in large groups, or herds, the size of which varies based on the specific habitat of the herd. In northern forests, deer are often solitary or in small family groups [C-13].

Economic and Other Importance

Deer hunting is an important recreational industry in Ontario [C-28].

C.6.5 Red Fox

Physical Appearance and Body Mass

The red fox (*Vulpes vulpes*) is a dog-sized canine, with a body that is 56 – 63 cm in length and a tail of 35 – 41 cm in length. Red foxes weigh between 3 and 7 kg, with the males slightly larger than the females [C-17]; average weight is 3.8 kg [C-28].

Habitat

The red fox is the most widely distributed carnivore in the world [C-17]. They utilize many types of habitats, though their habitat can be generally categorized as open country [C-28]. Specific habitat types that the red fox will use are cropland, rolling farmland, brush, pastures, hardwood stands, and coniferous forests. Red foxes prefer broken and diverse upland habitats. They are rare or absent from continuous stands of pine forests, moist conifer forests, and semiarid grasslands and deserts.

Each fox or family usually has a main underground den and one or more other burrows in their home range [C-17].

Diet

The red fox is primarily carnivorous; however it will feed on both animals and plant material. The red fox preys mainly on small mammals such as voles, mice, and rabbits. The fox will also eat game birds, poultry, insects, fruits, berries, seeds and nuts.

Red foxes hunt alone. In addition to hunting and occasional foraging, foxes will scavenge on carcasses or other refuse. Red foxes will often cache food in a hole for future use [C-17].

Temperature and Hibernation

Red foxes are active primarily at night or twilight. Red foxes are active year-round and do not hibernate [C-17].

Reproduction and Social Behaviour

Red fox pups are grown and reared in an underground den. The male fox assists the female in rearing young, bringing food to the den for the pups. A fox family generally consists of a mated pair or one male and several related females [C-17].

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Appendix D: Theoretical Basis and Input Parameters used in the Calculations of Doses to Non-Human Biota

D.1 INTRODUCTION

The computer code Assessment of Impact of Contaminants on Ecological Receptors (AICER) version 1.0.0.0 is used to calculate the doses to non-human biota for the existing environment. The theoretical basis on which the code was developed and the values of the parameters used in the code for the calculation of dose to non-human biota are presented below.

D.2 THEORETICAL BASIS FOR CALCULATION OF DOSE TO NON-HUMAN BIOTA

The ecological receptors could be exposed to radiation through different pathways. In addition to exposure to direct external gamma radiation from the waste storage facilities at the WWMF[26], receptors could also receive dose through an environmental pathway. The calculations of the internal dose and external dose due to the exposure from an environmental pathway are discussed below.

The biological characterization of these indicator species is summarized in Table D-1 and Table D-2 ([D-1], [D-2], [D-3], [D-4]).

D.2.1 Equations for Calculation of Internal Dose

Internal dose is calculated as follows [D-5]:

$$D_{int} = DC_{int} \text{ x } Ct$$

Where

D_{int} = internal dose rate (μGy/day)

DC_{int} = internal dose coefficient for aquatic or terrestrial organism (μGy/day per Bq/kg)

Ct = radionuclide concentration in tissue of the aquatic or terrestrial organism (Bq/kg)

The key to the calculation of the internal dose to any organism is to obtain the concentrations of radionuclides in the tissue of the organism (referred to as tissue concentration). The tissue concentration could be determined based on the measurement of field samples. If monitoring data are not available, the tissue concentration can be derived based on environmental media concentrations and transfer factors. Specifically, for plants, invertebrates and fish, the tissue concentration can be calculated with the following equation [D-5]:

$$C_t = C_m \text{ x BAF}$$

Where

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[26] Refer to Section 4.2 for details.

C_t = tissue concentration[27] (Bq/kg)

C_m = environmental media concentration (Bq/L or Bq/kg)

BAF = Indicator-specific, media-dependent bioaccumulation factors (L/kg or kg/kg)

For birds and mammals, the tissue concentration can be calculated with the following equation [D-5]:

$$C_t = \sum (C_x \times I_x \times TF)$$

Where for a given radionuclide,

C_x = concentration in the food chain item, x, of the bird or mammal (Bq/kg)

I_x = ingestion rate of the food item, x (kg/day)

TF = Indicator-specific transfer factor (d/kg)

D.2.2 Equations for Calculation of External Dose

The equations to calculate external dose are as follows [D-5]:

<u>For aquatic organisms</u>

External dose to aquatic organisms can be calculated with the following equation:

$$D_{ext} = DC_{ext}\{[OF_w + 0.5 \times OF_{ws} + 0.5 \times OF_{seds}] \times C_w + [OF_{sed} + 0.5 \times OF_{seds}] \times C_s\}$$

Where

D_{ext} = External dose rate (µGy/day)

DC_{ext} = External dose coefficient (µGy/day per Bq/kg)

C_s = radionuclide concentration in sediment (Bq/kg)

C_w = radionuclide concentration in water (Bq/L)

OF_w = Fraction of time in water (unitless)

OF_{ws} = Fraction of time on water surface (unitless)

OF_{sed} = Fraction of time in sediment (unitless)

OF_{seds} = Fraction of time on sediment surface (unitless)

<u>For terrestrial organisms</u>

External dose to terrestrial organisms can be calculated with the following equation:

$$D_{ext} = DC_{ext,s} \times OF_s \times C_s + DC_{ext,ss} \times OF_{ss} \times C_{ss}$$

Where

D_{ext} = External dose rate (µGy/day)

$DC_{ext,s}$ = External dose coefficient for exposure in soil (µGy/day per Bq/kg)

[27] Note that the concentration data in this document are in fresh weight (fw) basis.

$DC_{ext,ss}$ = External dose coefficient for exposure on soil surface (μGy/day per Bq/m^2)

C_s = radionuclide concentration in soil (Bq/kg)

C_{ss} = radionuclide concentration in soil surface (Bq/m^2)

OF_s = Fraction of time in soil (unitless)

OF_{ss} = Fraction of time on soil surface (unitless)

The values of parameters used in the equations, including the environmental concentrations are discussed in the following sections.

D.3 DOSE COEFFICIENTS

ICRP 108 provides the Dose Coefficients (DC) for the reference plants and animals discussed above [D-1]. The internal and external dose coefficients for those indicator species assessed in this work are summarized in Table D-3, Table D-4 and Table D-5.

For internal dose coefficients, the following weighting factors are used for tritium and alpha emitters [D-5]:

- For tritium, the weighting factor, or relative biological effectiveness, of 2 is used to calculate the weighted internal DC
- For alpha emitters, a radiation weighting factor of 10 is used to calculate the weighted internal DC as follows:

  Weighted DC = (unweighted DC x fraction of alpha component x 10) +
  [unweighted DC x (1-fraction of alpha component)]

The value of fraction of alpha component for a specific radionuclide is available in ICRP 108 [D-1].

D.4 TRANSFER FACTORS

Except grass and cedar, no indicator species are sampled for their tissue concentrations. Therefore, their tissue concentrations to be used for the calculation of internal dose must be estimated. In this assessment, the Bioaccumulation Factor (BAF) and Transfer Factor (TF) are used to estimate radionuclide concentrations in indicator species, as discussed in section D.2.1. This is consistent with CSA N288.6-12 [D-5]. The BAF and TF consist of the following:

- Transfer from water to fish, aquatic plant, amphibian and benthic invertebrate;
- Transfer form soil to invertebrate;
- Transfer from air and soil to plant; and,
- Transfer from air (inhalation), soil (intake), water (intake), and foodstuff to mammal and birds.

The values of these parameters are summarized in Table D-6 through Table D-12.

Table D-1: Biological Information for the Indicator Species (Plants, Invertebrates, Fish, and Amphibians) ([D-1], [D-2], [D-3], [D-4])

Parameters	Note	Unit	Cattail	Digger Crayfish	Northern Redbelly Dace	Spottail Shiner	Smallmouth Bass	Lake whitefish	Deepwater Sculpin	Grass	Eastern White Cedar	Earthworm	Bees	Northern Leopard Frog	Spring Peeper	Painted Turtle
Category	Specified category	NA	Aquatic Plant	Benthic Invertebrate	Fish	Fish	Fish	Fish	Fish	Small Plant	Large Plant	Invertebrate	Insect	Amphibian	Amphibian	Amphibian
Occup	Fraction of time in area of concern	%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Inhalation rate	Inhalation rate	m^3/day	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Water Intake	Water ingestion rate	L/day	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Soil Intake	Soil intake	kilogram/Day	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sediment Intake	Sediment intake	kilogram/Day	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Food Intake	Total food intake rate	kilogram/Day	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00E+00	0.0E+00	0.0E+00	0.0E+00	1.0E+00	0.0E+00	0.0E+00	0.0E+00
Food1Name	Food component 1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Grass	NA	NA	NA
Food1	Fraction of Food1	%	-	-	-	-	-	-	-	-	-	-	100%	-	-	-
Food2Name	Food component 2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Food2	Fraction of Food2	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Food3Name	Food component 3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Food3	Fraction of Food3	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Food4Name	Food component 4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Food4	Fraction of Food4	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OFa	Exposure to air	%	100%	100%	0%	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%
OFw	Fraction of time in water	%	25%	50%	50%	50%	100%	90%	50%	0%	0%	0%	0%	50%	0%	50%
OFws	Fraction of time on water surface	%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
OFs	Fraction of time in soil	%	0%	0%	0%	0%	0%	0%	0%	50%	50%	100%	0%	0%	0%	0%
OFss	Fraction of time on soil surface	%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	100%	0%
OFsed	Fraction of time in sediment	%	25%	50%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
OFseds	Fraction of time on sediment surface	%	25%	0%	0%	0%	0%	10%	50%	0%	0%	0%	0%	50%	0%	50%

Table D-2: Biological Information for the Indicator Species (Mammals, Birds, and Snake) ([D-1], [D-2], [D-3], [D-4])

Parameters	Note	Unit	Northern Water Snake	Wild Turkey	Red-Eyed Vireo	American Robin	Mallard Duck*	Bald Eagle	Muskrat	Northern Short-Tailed Shrew	Little Brown Bat	White Tailed Deer	Red Fox^
Category	Specified category	NA	Amphibian	Bird	Bird	Bird	Bird	Bird	Small Mammal	Small Mammal	Small Mammal	Large Mammal	Large Mammal
Occup	Fraction of time in area of concern	%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Inhalation rate	Inhalation rate	m3/day	0.0E+00	1.8E+00	0.02	2.00E-01	0.43	1.52	0.6	3.3E-02	2.3E-02	23	1.8
Water Intake	Water ingestion rate	L/day	0.0E+00	2.1E-01	4.0E-03	1.1E-02	6.0E-02	0.18	1.2E-01	4.2E-03	1.4E-03	6.8E+00	4.0E-01
Soil Intake	Soil intake	kilogram/Day	0.0E+00	2.0E-02	2.1E-04	0.00E+00	0.0E+00	0.0E+00	0.0E+00	9.7E-05	0.0E+00	7.1E-02	2.8E-03
Sediment Intake	Sediment intake	kilogram/Day	0.0E+00	0.0E+00	0.0E+00	0.00E+00	6.1E-03	0.0E+00	8.6E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Food Intake	Total food intake rate	kilogram/Day	0.0E+00	6.7E-01	1.4E-02	1.2E-01	2.5E-01	0.588	3.6E-01	1.3E-02	4.7E-03	1.1E+01	3.1E-01
Food1Name	Food component 1	NA	NA	Earthworm	Earthworm	Earthworm	Benthic Invertebrates	Fish	Crayfish	Earthworm	Insects	Grass	Grass
Food1	Fraction of Food1	%	-	20%	90%	90%	75%	80%	2%	100%	100%	50%	15%
Food2Name	Food component 2	NA	NA	Grass	Grass	Grass	Aquatic Plants	Rabbit	Aquatic Plants	NA	NA	Foliage	Rabbit
Food2	Fraction of Food2	%	-	20%	10%	10%	25%	10%	98%	-	-	50%	40%
Food3Name	Food component 3	NA	NA	Foliage	NA	NA	NA	Mallard	NA	NA	NA	NA	American Robin
Food3	Fraction of Food3	%	-	60%	-	-	-	10%	-	-	-	-	20%
Food4Name	Food component 4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Rat
Food4	Fraction of Food4	%	-	-	-	-	-	-	-	-	-	-	25%
OFa	Exposure to air	%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
OFw	Fraction of time in water	%	50%	0%	0%	0%	20%	0%	50%	0%	0%	0%	0%
OFws	Fraction of time on water surface	%	0%	0%	0%	0%	80%	0%	0%	0%	0%	0%	0%
OFs	Fraction of time in soil	%	0%	0%	0%	0%	0%	0%	0%	50%	0%	0%	0%
OFss	Fraction of time on soil surface	%	0%	100%	0%	100%	0%	0%	0%	50%	0%	100%	100%
OFsed	Fraction of time in sediment	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
OFseds	Fraction of time on sediment surface	%	50%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%

Note: In order to ensure a conservative estimate of the dose received by receptors, it has been assumed that migratory birds (Red-Eyed Vireo, American Robin, and Mallard Duck) spend 100% of their time on site.

*For the purposes of this assessment, it has been assumed that the Mallard Duck spends 100% of the time in the water.

^For the purposes of this assessment, it has been assumed that the Red Fox spend 100% of the time on the soil surface.

Table D-3: Internal Dose Coefficients (µGy/day)/ (Bq/kg) [D-1]

Radionuclide	Large Mammal	Small Mammal	Bird	Amphibian	Benthic Invertebrate	Insect	Invertebrate	Large Plant	Small Plant	Aquatic Plant	Fish
Tritium (HTO)	1.6E-04	1.6E-04	1.6E-04	1.6E-04	1.6E-04	1.6E-04	1.6E-04	1.6E-04	1.6E-04	1.6E-04	1.6E-04
C-14	6.8E-04	6.8E-04	6.8E-04	6.8E-04	6.8E-04	6.8E-04	6.8E-04	6.8E-04	6.8E-04	6.8E-04	6.8E-04
Co-60	2.0E-02	4.0E-03	5.7E-03	2.6E-03	5.0E-03	1.6E-03	1.8E-03	1.8E-02	1.8E-03	2.1E-03	5.1E-03
I-131	6.0E-03	3.1E-03	3.4E-03	2.8E-03	3.3E-03	2.6E-03	2.7E-03	5.9E-03	2.6E-03	2.7E-03	3.3E-03
Cs-134	1.5E-02	4.1E-03	5.3E-03	3.1E-03	4.8E-03	2.3E-03	2.6E-03	1.4E-02	2.5E-03	2.7E-03	4.9E-03
Cs-137	8.2E-03	4.1E-03	4.5E-03	3.7E-03	4.4E-03	3.2E-03	3.4E-03	7.8E-03	3.4E-03	3.3E-03	4.4E-03

Table D-4: External Dose Coefficient (Mammals, Birds, and Amphibians) [D-1]

Radionuclide	Large Mammal		Small Mammal			Bird			Amphibian		
	on soil/planar [(µGy/day)/ (Bq/m²)]	in soil /volume [(µGy/day)/ (Bq/kg)]	in water/infinite [(µGy/day)/ (Bq/kg)]	on soil/planar [(µGy/day)/ (Bq/m²)]	in soil /volume [(µGy/day)/ (Bq/kg)]	on soil/planar [(µGy/day)/ (Bq/m²)]	in soil /volume [(µGy/day)/ (Bq/kg)]	in water/infinite [(µGy/day)/ (Bq/kg)]	in water/infinite [(µGy/day)/ (Bq/kg)]	on soil/planar [(µGy/day)/ (Bq/m²)]	on soil /volume [(µGy/day)/ (Bq/kg)]
Tritium (HTO)	0.00E+00	0.00E+00	8.50E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.50E-12	5.90E-11	0.00E+00	0.00E+00
C-14	0.00E+00	0.00E+00	4.30E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.30E-07	1.40E-06	0.00E+00	0.00E+00
Co-60	9.70E-05	6.20E-03	3.00E-02	1.90E-04	2.90E-02	1.80E-04	1.10E-02	3.00E-02	3.30E-02	1.90E-04	1.20E-02
I-131	1.50E-05	8.90E-04	4.50E-03	3.10E-05	4.30E-03	2.90E-05	1.70E-03	4.50E-03	5.10E-03	3.10E-05	1.90E-03
Cs-134	6.10E-05	3.80E-03	1.90E-02	1.20E-04	1.90E-02	1.20E-04	7.00E-03	1.90E-02	2.10E-02	1.30E-04	7.60E-03
Cs-137	2.20E-05	1.40E-03	6.70E-03	4.50E-05	6.80E-03	4.30E-05	2.60E-03	6.70E-03	7.60E-03	4.60E-05	2.70E-03

Table D-5: External Dose Coefficient (Invertebrates, Plants, and Fish) [D-1]

Radionuclide	Benthic Invertebrate	Insect		Invertebrate	Large Plant		Small Plant		Aquatic Plant	Fish
	in water/infinite [(µGy/day)/ (Bq/kg)]	on soil/planar [(µGy/day)/ (Bq/m²)]	on soil /volume [(µGy/day)/ (Bq/kg)]	in soil /volume [(µGy/day)/ (Bq/kg)]	Layer/planar [(µGy/day)/ (Bq/m²)]	Layer /volume [(µGy/day)/ (Bq/kg)]	Layer/planar [(µGy/day)/ (Bq/m²)]	Layer /volume [(µGy/day)/ (Bq/kg)]	in water/infinite [(µGy/day)/ (Bq/kg)]	in water/infinite [(µGy/day)/ (Bq/kg)]
Tritium (HTO)	1.80E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.60E-08	8.50E-12
C-14	5.10E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.20E-06	4.30E-07
Co-60	3.10E-02	1.90E-04	1.20E-02	3.10E-02	1.30E-04	9.30E-03	4.30E-04	1.10E-02	3.40E-02	3.10E-02
I-131	4.60E-03	3.20E-05	1.90E-03	4.60E-03	2.20E-05	1.50E-03	7.40E-05	1.80E-03	5.30E-03	4.60E-03
Cs-134	1.90E-02	1.30E-04	7.60E-03	2.00E-02	8.60E-05	6.00E-03	2.90E-04	7.40E-03	2.10E-02	1.90E-02
Cs-137	6.90E-03	4.60E-05	2.80E-03	7.30E-03	3.10E-05	2.20E-03	1.10E-04	2.70E-03	7.90E-03	6.80E-03

Table D-6: Transfer from Environmental Media to Indicator Species

Radionuclide	From Water to Fish (L/kg fw)	From Water to Aquatic Plant (L/kg fw)	From Water to Benthic Invertebrate (L/kg fw)	From Soil to Invertebrate (kg/kg fw)	From Water to Amphibian (L/kg fw)
Tritium (HTO)	7.5E-01	7.5E-01	7.5E-01	1.5E+02	1.0E+00
C-14	5.7E+03	5.9E+03	5.2E+03	4.3E+02	7.3E+03
Co-60	5.4E+01	7.9E+02	1.1E+02	5.6E-03	8.2E+01
I-131	6.0E+00	7.1E+01	9.6E+00	1.7E-01	2.6E+02
Cs-134	3.5E+03	2.2E+02	9.9E+01	5.7E-02	1.6E+03
Cs-137	3.5E+03	2.2E+02	9.9E+01	5.7E-02	1.6E+03

Note: For invertebrate and amphibian, the values are taken from ICRP 114 [D-6]; the values for other species are taken from CSA N288.1-14 [D-7].

Table D-7: Soil to Plant Transfer Factor

Radionuclide	From Soil to Large Plant (kg fw plant/kg wet soil)	From Soil to Small Plant (kg fw plant/kg wet soil)
Tritium (HTO)	0.0E+00	0.0E+00
C-14	0.0E+00	0.0E+00
Co-60	4.9E-02	1.1E-02
I-131	5.2E-02	1.2E-02
Cs-134	5.5E-02	1.3E-02
Cs-137	5.5E-02	1.3E-02

Note: The values are derived based on the concentration ratio of the contaminant between the soil and plant and the dw/fw ratio for plant products [D-7].

Table D-8: Air to Plant Transfer Factor

Radionuclide	Small Plant (m^3/kg fw)	Large Plant (m^3/kg fw)
Tritium (HTO)	4.95E+01	8.04E+00
C-14	4.76E+02	2.07E+03
Co-60	2.70E+04	3.31E+04
I-131	1.41E+04	1.22E+04
Cs-134	2.68E+04	3.26E+04
Cs-137	2.71E+04	3.33E+04

Note: The air to plant transfer factor corresponds to P14 in CSA N288.1-14 [D-7]. Note for Tritium and C-14, a specific activity model is used to derive this value.

Table D-9: Transfer Factors from Air (Inhalation) to Mammals and Birds

Radionuclide	Small Mammal (d/kg fw)	Large Mammal (d/kg fw)	Bird (d/kg fw)
Tritium (HTO)	8.60E-01	7.37E-01	1.11E+00
C-14	0.00E+00	0.00E+00	0.00E+00
Co-60	3.08E-01	2.05E-02	1.66E+00
I-131	2.90E-01	2.02E-02	5.48E-03
Cs-134	6.93E+01	9.45E-02	1.70E+00
Cs-137	6.93E+01	9.45E-02	1.70E+00

Note: The transfer factor of Tritium corresponds to P_{15} (m^3/kg fw) in CSA N288.1-14. The transfer factors for other radionuclides correspond to F_{inh} in CSA N288.1-14, which are equal to F_{ing} x II [D-7] .

Table D-10: Transfer Factor from Soil/Sediment (Intake) to Mammals and Birds

Radionuclide	Small Mammal (d/kg fw)	Large Mammal (d/kg fw)	Bird (d/kg fw)
Tritium (HTO)	0.00E+00	0.00E+00	0.00E+00
C-14	0.00E+00	0.00E+00	0.00E+00
Co-60	1.80E-01	1.20E-02	9.70E-01
I-131	4.60E-01	3.20E-02	8.70E-03
Cs-134	1.10E+02	1.50E-01	2.70E+00
Cs-137	1.10E+02	1.50E-01	2.70E+00

Note: The soil ingestion dose from tritium and C-14 is negligible [D-5]; for other radionuclides, the transfer factors correspond to F_{ing} in CSA N288.1-14 [D-7].

Table D-11: Transfer Factor from Water (Intake) to Mammals and Birds

Radionuclide	Small Mammal (d/kg fw)	Large Mammal (d/kg fw)	Bird (d/kg fw)
Tritium (HTO)	2.89E-01	2.31E-01	1.54E-01
C-14	0.00E+00	0.00E+00	0.00E+00
Co-60	1.80E-01	1.20E-02	9.70E-01
I-131	4.60E-01	3.20E-02	8.70E-03
Cs-134	1.10E+02	1.50E-01	2.70E+00
Cs-137	1.10E+02	1.50E-01	2.70E+00

Note: The transfer factor for tritium (HTO) (L/kg fw) corresponds to P25_HTO in CSA N288.1-14. For other radionuclides, the transfer factor corresponds to F_{ing} in CSA N288.1-14 [D-7].

Table D-12: Transfer Factor from Foodstuff to Mammals and Birds

Radionuclide	Food Intake for Small Mammals (d/kg fw)	Food Intake for Large Mammals (d/kg fw)	Food Intake for Birds (d/kg fw)
Tritium (HTO)	4.3E-01	4.9E-01	6.0E-01
C-14	2.0E+00	2.0E+00	2.0E+00
Co-60	1.8E-01	1.2E-02	9.7E-01
I-131	4.6E-01	3.2E-02	8.7E-03
Cs-134	1.1E+02	1.5E-01	2.7E+00
Cs-137	1.1E+02	1.5E-01	2.7E+00

Note: The transfer factors for tritium (HTO) and C-14 correspond to P45_HTO and P45_C-14 (unitless), respectively. For other radionuclides, the transfer factor corresponds to F_{ing} in CSA N288.1-14 [D-7].

D.5 AIR CONCENTRATIONS USED IN DOSE CALCULATION

In addition to the parameters discussed above, the concentrations of radionuclides in different media are required in the code AICER for dose calculation.

In this report, Tritium (HTO), C-14, Cs-134, Cs-137, Co-60 and I-131 were selected for dose calculation. These radionuclides were selected because of their prevalence in the environment and their relevance to the emission of WWMF and other nuclear facilities at the Bruce nuclear site, specifically BNGS-A and BNGS-B which are the major contributors to radiological emissions. The concentrations of these radionuclides in environmental media such as surface water, soil, and vegetation have been measured as discussed in Section 4.0. For air, the estimated concentrations, as presented below, were used for the dose calculation.

Radionuclide concentrations in air were estimated using the code IMPACT, based on the emission data for the period of 2009 to 2013 as presented in Section 2.2.9.1. The meteorological data for the Bruce nuclear site for the same period were used to derive Triple Joint Frequency (TJF) of wind speed, direction and stability class (Table D-13), which is the input data to the code IMPACT.

Table D-13: Annual Average TJF at the Bruce Nuclear Site, 2009 to 2013

Stability Class	Wind Direction (wind blowing from)	Wind Speed, u (m/s)						
		u ≤ 2	2 < u ≤ 3	3 < u ≤ 4	4 < u ≤ 5	5 < u ≤ 6	u > 6	Total
		Frequency (%) at 10 m Height						
A	N	0.27	0.46	0.31	0.06	0.02	0.03	**1.15**
	NNE	0.36	0.45	0.37	0.11	0.02	0.01	**1.32**
	NE	0.24	0.21	0.10	0.01	0.01	0.01	**0.58**
	ENE	0.30	0.19	0.12	0.01	0.00	0.00	**0.61**
	E	0.41	0.25	0.07	0.02	0.01	0.00	**0.76**
	ESE	0.32	0.18	0.10	0.03	0.00	0.00	**0.64**
	SE	0.29	0.24	0.08	0.02	0.00	0.00	**0.64**
	SSE	0.34	0.14	0.11	0.02	0.01	0.00	**0.61**
	S	0.25	0.17	0.12	0.04	0.01	0.00	**0.59**
	SSW	0.29	0.15	0.14	0.08	0.02	0.01	**0.68**
	SW	0.25	0.27	0.19	0.08	0.01	0.01	**0.82**
	WSW	0.20	0.33	0.20	0.04	0.02	0.02	**0.82**
	W	0.21	0.48	0.22	0.03	0.02	0.02	**0.98**
	WNW	0.26	0.51	0.18	0.03	0.01	0.00	**1.00**
	NW	0.41	0.61	0.20	0.05	0.03	0.01	**1.29**
	NNW	0.42	0.73	0.23	0.08	0.03	0.00	**1.48**
	Total	**4.82**	**5.36**	**2.72**	**0.73**	**0.22**	**0.12**	**13.97**
B	N	0.02	0.13	0.48	0.37	0.15	0.10	**1.25**
	NNE	0.09	0.42	0.75	0.55	0.18	0.07	**2.06**
	NE	0.06	0.13	0.20	0.14	0.04	0.03	**0.61**
	ENE	0.12	0.13	0.13	0.12	0.06	0.01	**0.56**
	E	0.08	0.18	0.13	0.03	0.02	0.00	**0.44**
	ESE	0.04	0.11	0.09	0.09	0.06	0.03	**0.43**
	SE	0.10	0.23	0.18	0.07	0.07	0.04	**0.68**
	SSE	0.13	0.28	0.34	0.17	0.10	0.06	**1.08**
	S	0.14	0.28	0.35	0.29	0.16	0.10	**1.31**
	SSW	0.10	0.26	0.41	0.46	0.42	0.42	**2.08**
	SW	0.06	0.38	0.96	1.09	0.48	0.19	**3.16**
	WSW	0.02	0.23	0.30	0.14	0.09	0.06	**0.84**
	W	0.01	0.16	0.27	0.14	0.08	0.12	**0.78**
	WNW	0.04	0.15	0.25	0.22	0.15	0.13	**0.94**
	NW	0.06	0.22	0.28	0.35	0.18	0.15	**1.23**
	NNW	0.08	0.41	0.49	0.45	0.25	0.16	**1.84**
	Total	**1.14**	**3.69**	**5.64**	**4.68**	**2.50**	**1.66**	**19.31**

Table D-13: Annual Average TJF at the Bruce Nuclear Site, 2009 to 2013 (continued)

Stability Class	Wind Direction (wind blowing from)	Wind Speed, u (m/s)						
		u ≤ 2	2 < u ≤ 3	3 < u ≤ 4	4 < u ≤ 5	5 < u ≤ 6	u > 6	Total
		Frequency (%) at 10 m Height						
C	N	0.00	0.01	0.05	0.05	0.04	0.04	**0.19**
	NNE	0.01	0.03	0.04	0.05	0.01	0.00	**0.15**
	NE	0.01	0.02	0.01	0.02	0.00	0.00	**0.07**
	ENE	0.04	0.06	0.03	0.02	0.01	0.00	**0.16**
	E	0.02	0.02	0.00	0.00	0.00	0.00	**0.05**
	ESE	0.01	0.00	0.00	0.01	0.01	0.01	**0.04**
	SE	0.06	0.03	0.01	0.01	0.00	0.01	**0.12**
	SSE	0.07	0.17	0.14	0.05	0.02	0.02	**0.48**
	S	0.10	0.18	0.16	0.11	0.09	0.01	**0.65**
	SSW	0.02	0.14	0.15	0.07	0.12	0.06	**0.56**
	SW	0.03	0.14	0.52	0.69	0.29	0.27	**1.94**
	WSW	0.00	0.08	0.21	0.32	0.27	0.62	**1.50**
	W	0.00	0.05	0.10	0.14	0.16	0.29	**0.75**
	WNW	0.01	0.04	0.06	0.11	0.11	0.16	**0.49**
	NW	0.00	0.01	0.03	0.06	0.11	0.18	**0.39**
	NNW	0.02	0.05	0.12	0.14	0.12	0.24	**0.69**
	Total	**0.42**	**1.05**	**1.63**	**1.86**	**1.36**	**1.91**	**8.24**
D	N	0.00	0.05	0.60	0.52	0.35	0.34	**1.87**
	NNE	0.01	0.02	0.35	0.32	0.20	0.15	**1.05**
	NE	0.05	0.08	0.41	0.31	0.11	0.08	**1.03**
	ENE	0.15	0.25	0.42	0.14	0.05	0.04	**1.04**
	E	0.11	0.04	0.14	0.05	0.03	0.00	**0.37**
	ESE	0.04	0.03	0.17	0.13	0.08	0.03	**0.48**
	SE	0.13	0.14	0.39	0.26	0.12	0.07	**1.12**
	SSE	0.45	0.84	0.93	0.34	0.18	0.06	**2.80**
	S	0.56	0.50	1.08	0.75	0.29	0.15	**3.32**
	SSW	0.20	0.52	1.02	0.77	0.71	0.60	**3.82**
	SW	0.01	0.23	0.56	0.55	0.44	0.54	**2.33**
	WSW	0.01	0.07	0.41	0.62	0.54	1.01	**2.66**
	W	0.00	0.03	0.32	0.47	0.41	0.85	**2.08**
	WNW	0.00	0.08	0.37	0.51	0.62	0.68	**2.26**
	NW	0.00	0.05	0.47	0.56	0.56	0.58	**2.23**
	NNW	0.00	0.07	0.59	0.66	0.46	0.59	**2.37**
	Total	**1.72**	**2.99**	**8.23**	**6.96**	**5.16**	**5.77**	**30.82**

Table D-13: Annual Average TJF at the Bruce Nuclear Site, 2009 to 2013 (continued)

Stability Class	Wind Direction (wind blowing from)	Wind Speed, u (m/s)						
		u ≤ 2	2 < u ≤ 3	3 < u ≤ 4	4 < u ≤ 5	5 < u ≤ 6	u > 6	Total
		Frequency (%) at 10 m Height						
E	N	0.02	0.28	0.07	0.00	0.00	0.00	**0.37**
	NNE	0.05	0.21	0.12	0.00	0.00	0.00	**0.38**
	NE	0.19	0.23	0.05	0.00	0.00	0.00	**0.47**
	ENE	0.47	0.31	0.01	0.00	0.00	0.00	**0.79**
	E	0.40	0.19	0.02	0.00	0.00	0.00	**0.61**
	ESE	0.21	0.12	0.01	0.00	0.00	0.00	**0.34**
	SE	0.48	0.45	0.01	0.00	0.00	0.00	**0.95**
	SSE	1.00	0.71	0.02	0.00	0.00	0.00	**1.73**
	S	1.01	0.67	0.02	0.00	0.00	0.00	**1.70**
	SSW	0.46	0.49	0.05	0.00	0.00	0.00	**0.99**
	SW	0.15	0.23	0.06	0.00	0.00	0.00	**0.43**
	WSW	0.02	0.05	0.04	0.00	0.00	0.00	**0.11**
	W	0.02	0.08	0.03	0.00	0.00	0.00	**0.12**
	WNW	0.06	0.18	0.05	0.00	0.00	0.00	**0.29**
	NW	0.04	0.16	0.06	0.00	0.00	0.00	**0.26**
	NNW	0.04	0.30	0.09	0.00	0.00	0.00	**0.42**
	Total	**4.62**	**4.67**	**0.70**	**0.00**	**0.00**	**0.00**	**9.99**
F	N	0.46	0.27	0.00	0.00	0.00	0.00	**0.73**
	NNE	0.65	0.33	0.00	0.00	0.00	0.00	**0.98**
	NE	0.94	0.28	0.00	0.00	0.00	0.00	**1.22**
	ENE	1.25	0.23	0.00	0.00	0.00	0.00	**1.48**
	E	1.46	0.21	0.00	0.00	0.00	0.00	**1.67**
	ESE	0.99	0.16	0.00	0.00	0.00	0.00	**1.15**
	SE	1.21	0.28	0.00	0.00	0.00	0.00	**1.49**
	SSE	1.49	0.25	0.00	0.00	0.00	0.00	**1.74**
	S	1.82	0.33	0.00	0.00	0.00	0.00	**2.15**
	SSW	1.08	0.22	0.00	0.00	0.00	0.00	**1.30**
	SW	0.60	0.17	0.00	0.00	0.00	0.00	**0.77**
	WSW	0.30	0.12	0.00	0.00	0.00	0.00	**0.42**
	W	0.26	0.14	0.00	0.00	0.00	0.00	**0.40**
	WNW	0.40	0.17	0.00	0.00	0.00	0.00	**0.57**
	NW	0.59	0.17	0.00	0.00	0.00	0.00	**0.76**
	NNW	0.62	0.24	0.00	0.00	0.00	0.00	**0.86**
	Total	**26.84**	**21.32**	**18.90**	**14.23**	**9.25**	**9.46**	**17.68**
Grand Total		**24.35**	**20.37**	**19.75**	**15.55**	**9.09**	**10.90**	**100.00**

The air concentrations were estimated at four locations. They are located west, north, east and south of the WWMF, each approximately 100 m from the center of the WWMF. The maximum concentrations in these four locations, presented in Table D-14 were used in the dose calculation.

Table D-14: Estimated Concentration of Radionuclides in Air

Radionuclide	C-14	Cs-134	Cs-137	Co-60	Tritium	I-131
Concentration (Bq/m^3)	4.3E-02	1.3E-06	1.3E-06	1.3E-06	7.8E+01	1.3E-06

It should be noted that emissions of airborne particulates from the WWMF are measured. Particulates consist of a group of radionuclides. For the purposes of the ERA, the total concentrations of particulates were conservatively assigned to each of the radionuclides Cs-134, Cs-137 and Co-60.

D.6 SAMPLE CALCULATIONS

Doses to non-human biota were calculated using the AICER code; the results are presented in Table 4-10. The sample calculations were performed for Mallard and Deer as example receptors to illustrate the contributions of different pathways, presented in Table D-15 and Table D-16.

Table D-15: Sample Calculation for Mallard

Biological parameter	Unit	Acronym	Values	Note
Water intake	L/d	A	0.06	Table D-2
Inhalation rate	m^3/d	B	0.43	Table D-2
Total food intake	g (fw)/d	C	250	Table D-2
Benthos fraction	unitless	D	0.75	Table D-2
Aquatic veg fraction	unitless	E	0.25	Table D-2
Sediment intake	g (ww)/d	F	6.1	Table D-2
Fraction of time in water surface	unitless	Gws	0.8	Table D-2
Fraction of time in water column	unitless	Gw	0.2	Table D-2
Cs-137				
Air concentration	Bq/m^3	H	1.30E-06	Estimated concentration
Transfer factor-air	d/kg (fw)	TFa	1.70E+00	Table D-9
Water concentration	Bq/L	I	5.00E-01	Measured concentration
Transfer factor-water	d/kg (fw)	TFw	2.70E+00	Table D-11
Sediment concentration	Bq/kg (ww)	J	1.70E+00	Measured concentration
Transfer factor-soil/sediment	d/kg (fw)	TFs	2.70E+00	Table D-10
Aquatic plant concentration	Bq/kg (fw)	K	1.10E+02	= Ix Qw-p (Qw-p can be found in Table D-6)
Benthos concentration	Bq/kg (fw)	L	4.95E+01	= I x Qw-b (Qw-b can be found in Table D-6)
Transfer factor-food	d/kg (fw)	TFf	2.70E+00	Table D-12
Tissue concentration	Bq/kg (fw)	M	4.37E+01	= B x H x TFa+A x I x TFw+F x J x TFs/1000+(C x D x L+C x E x K)x TFf/1000
Internal dose coefficient	uGy/d per Bq/kg	N	4.50E-03	Table D-3
Internal dose	uGy/d	O	1.97E-01	= M x N
External dose coefficient	uGy/d per Bq/kg	P	6.70E-03	Table D-4
External dose	uGy/d	Q	2.01E-03	= (Gw+Gws*0.5)x Ix P
Total dose	uGy/d	R	1.99E-01	= O+Q
Total dose	uGy/h		8.28E-03	= R/24 (unit conversion)
HTO				
Air concentration	Bq/m^3	H	7.80E+01	Estimated concentration
Transfer factor-air	m^3/kg (fw)	Tfa	1.11E+00	Table D-9
Water concentration	Bq/L	I	3.32E+03	Measured concentration

Biological parameter	Unit	Acronym	Values	Note
Transfer factor-water	L/kg (fw)	TFw	1.54E-01	Table D-11
Sediment concentration	Bq/kg (ww)	J	2.66E+03	Based on the measured water concentration, taking into account water content of 80% in sediment.
Transfer factor-soil/sediment	d/kg (fw)	TFs	0.00E+00	Table D-10
Aquatic plant concentration	Bq/kg (fw)	K	2.49E+03	= Ix Qw-p (Qw-p can be found in Table D-6)
Benthos concentration	Bq/kg (fw)	L	2.49E+03	= I x Qw-b (Qw-b can be found in Table D-6)
Transfer factor-food	unitless	TFf	6.00E-01	Table D-12
Tissue concentration	Bq/kg (fw)	M	2.09E+03	= H x TFa+ I x TFw+F x J x TFs/1000+(D x L+ D x K)x TFf
Internal dose coefficient	uGy/d per Bq/kg	N	1.58E-04	Table D-3
Internal dose	uGy/d	O	3.31E-01	= M x N
External dose coefficient	uGy/d per Bq/kg	P	8.50E-12	Table D-4
External dose	uGy/d	Q	1.69E-08	= (Gw+Gws*0.5)x Ix P
Total dose	uGy/d	R	3.31E-01	= O+Q
Total dose	uGy/h		1.38E-02	= R/24 (unit conversion)

Table D-16: Sample Calculation for Deer

Biological parameter	Unit	Acronym	Values	Note
Water intake	L/d	A	6.8	Table D-2
Inhalation rate	m^3/d	B	23	Table D-2
Total food intake	g (fw)/d	C	11000	Table D-2
Grass fraction	unitless	D	0.5	Table D-2
Cedar fraction	unitless	E	0.5	Table D-2
Soil intake	g (ww)/d	F	71	Table D-2
Fraction of time on soil surface	unitless	G	1	Table D-2
Cs-137				
Air concentration	Bq/m^3	H	1.30E-06	Estimated concentration
Transfer factor-air	d/kg (fw)	TFa	9.45E-02	Table D-9
Water concentration	Bq/L	I	5.00E-01	Measured concentration
Transfer factor-water	d/kg (fw)	TFw	1.50E-01	Table D-11
Soil concentration	Bq/kg (ww)	J	2.92E+01	Measured concentration
Soil concentration (surface)	Bq/m^2	K	5.73E+02	Based on measurement
Transfer factor-soil	d/kg (fw)	TFs	1.50E-01	Table D-10
Grass concentration	Bq/kg (ww)	L	1.65E+00	Measured concentration
Cedar concentration	Bq/kg (ww)	M	1.60E+00	Measured concentration
Transfer factor-food	d/kg (fw)	TFf	1.50E-01	Table D-12
Tissue concentration	Bq/kg (fw)	O	3.50E+00	= Bx H xTFa+Ax I x TFw+Fx Jx TFs/1000+(Cx E x M+C x D x L)x TFf/1000
Internal dose coefficient	uGy/d per Bq/kg	P	8.20E-03	Table D-3
Internal dose	uGy/d	Q	2.87E-02	= Ox P
External dose coefficient	uGy/d per Bq/m^2	R	2.20E-05	Table D-4
External dose	uGy/d	S	1.50E-02	= 1.19x K x R (1.19 is a conversion factor from wet weight to dry weight)
Total dose	uGy/d	T	4.37E-02	= Q+S
Total dose	uGy/h		1.82E-03	= T/24 (unit conversion)
HTO				
Air concentration	Bq/m^3	H	7.80E+01	Estimated concentration
Transfer factor-air	m^3/kg (fw)	Tfa	7.37E-01	Table D-9

Biological parameter	Unit	Acronym	Values	Note
Water concentration	Bq/L	I	3.32E+03	Measured concentration
Transfer factor-water	L/kg (fw)	TFw	2.31E-01	Table D-11
Soil concentration	Bq/kg (ww)	J	5.12E+02	Measured concentration
Soil concentration (surface)	Bq/m^2	K	2.45E+02	Based on measurement
Transfer factor-soil	d/kg (fw)	TFs	0.00E+00	Table D-10
Grass concentration	Bq/kg (ww)	L	9.21E+02	Measured concentration
Cedar	Bq/kg (ww)	M	1.24E+03	Measured concentration
Transfer factor-food	unitless	TFf	4.90E-01	Table D-12
Tissue concentration	Bq/kg (fw)	O	1.35E+03	= H xTFa+ I x TFw+Fx Jx TFs/1000+ E x M x TFf + D x Lx TFf
Internal dose coefficient	uGy/d per Bq/kg	P	1.58E-04	Table D-3
Internal dose	uGy/d	Q	2.14E-01	= Ox P
External dose coefficient	uGy/d per Bq/m^2	R	0.00E+00	Table D-4
External dose	uGy/d	S	0.00E+00	= 1.19x K x R (1.19 is a conversion factor from wet weight to dry weight)
Total dose	uGy/d	T	2.14E-01	= Q+S
Total dose	uGy/h		8.91E-03	= T/24 (unit conversion)

D.7 REFERENCES

[D-1] ICRP. Environmental Protection: the Concept and Use of Reference Animals and Plants, ICRP Publication 108, Oct 2008.

[D-2] AMEC NSS. OPG's Deep Geologic Repository for Low and Intermediate Level Waste Radiation and Radioactivity Technical Support Document, NWMO DGR-TR-2011-06, 2011

[D-3] SENES. 2005. Ecological risk assessment technical support document for WWMF RWS project, June 2005.

[D-4] US EPA. Wildlife exposure factors handbook, EPA/600/R-93/187a, 1993.

[D-5] Canadian Standards Association. Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills, CSA N288.6-12, Dec 2012.

[D-6] ICRP Publication 114: Environmental Protection: Transfer Parameters for Reference Animals and Plants. Aug 2011.

[D-7] Canadian Standards Association. Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities. CSA N288.1-14. March 2014.

Appendix E: Discussion of Sediment COPC, Sediment Ecological Benchmarks and Benthic Invertebrates

E.1 SEDIMENT COPC DISCUSSION

Barium was identified at concentrations ranging from 20.6 mg/kg to 91.2 mg/kg. One sample marginally exceeded the 98th percentile of 89 mg/kg from the sediment background data. During the subsequent sampling period, concentrations were below the 98th percentile. Barium has not been identified in other media at the Site and concentrations are still within ranges that are likely to occur naturally (i.e., the 98th percentile of the dataset as a whole is 125 mg/kg). Barium is therefore not considered a COPC.

Bismuth concentrations in sediment range from <0.10 mg/kg to 0.46 mg/kg. Concentrations in samples used to represent background are 0.175 mg/kg. Concentrations greater than background were identified at WD-4 (0.46 mg/kg). Although bismuth is greater than the data set used to represent background, bismuth is not known to be very toxic [E-1]. Bismuth will not be addressed as a COPC.

Background concentrations are not provided for boron in the MNDM database. Boron is a naturally occurring mineral which is released into the aquatic environment through weathering of rocks. Boron can also be released from industrial activities. Boron has not been identified as a COPC in surface water or soil. Boron concentrations in sediment range from 7.8 mg/kg to 19.6 mg/kg, with no specific spikes which would suggest impacts. Naturally occurring concentrations of boron in soil have been reported to be 36 mg/kg in Ontario [E-2]. Based on the information available, boron is not considered a COPC in sediment.

Cadmium was detected at concentrations up to 0.884 mg/kg; this maximum concentration exceeds the MOECC LEL of 0.6 mg/kg but not the SEL of 10 mg/kg or CCME PEL of 3.5 mg/kg. However, cadmium concentrations do not exceed the MOECC background level of 1 mg/kg [E-3]. As such cadmium is not considered a COPC.

Calcium concentrations in sediment ranged from 54,000 mg/kg to 164,000 mg/kg. In the sediment samples used to provide an indication of background concentration, calcium had an upper detection limit of 65,000 mg/kg and analysis predominantly identified calcium as >65,000 mg/kg. Calcium is a biological requirement and is generally not considered to be toxic. Calcium will not be addressed as a COPC.

Cesium concentrations in sediment ranged from 0.3 mg/kg to 0.918 mg/kg. Concentrations in samples used to represent background had a 98th percentile concentration of 0.78 mg/kg. Concentrations greater than 0.78 mg/kg were only identified at GS-1 in May 2014. Other sediment samples collected at this location and locations nearby (i.e., April 2014 and October 2014 at GS-1) did not identify concentrations above background. Cesium was not detected in surface water. The sediment radionuclide monitoring measured maximum concentrations of 1.7 Bq/kg of Cs-137 in August 2014 and 0.5 Bq/kg of Cs-134 in July 2013 at the same location (Location GS-1); this is equal to a total chemical cesium concentration of

0.0005 ng/kg at Location GS-1. The concentration derived from measurement of the radionuclides is nine orders of magnitude less than the measured cesium concentration in sediment. Therefore it can be concluded that the cesium concentration which was measured above background is not due to emissions from the WWMF, as cesium emitted from the WWMF would be in radionuclide form. As such, the level of cesium observed at this location is likely anomalous or associated with natural variability. Cesium is not therefore considered a COPC.

Magnesium concentrations in sediment range from 17,400 mg/kg to 40,500 mg/kg. In the sediment samples used to provide an indication of background concentration, magnesium had an upper detection limit of 14,000 mg/kg and analysis predominantly identified magnesium as >14,000 mg/kg. Magnesium is an essential nutrient and is generally not considered to be toxic. Magnesium will not be addressed as a COPC.

Mercury concentrations in sediment ranged from 0.05 to 0.18 mg/kg, with concentrations of most samples measured below 0.07 mg/kg. The maximum concentration of 0.18 mg/kg exceeded the ISQG of 0.17 mg/kg [E-4], but not the LEL of 0.2 mg/kg [E-5]. MOE Table 1 gives a background concentration for mercury in sediment of 0.2 mg/kg [E-2]. Therefore, mercury is not considered a COPC.

Nickel was identified at concentrations up to 20.6 mg/kg which exceed the MOECC LEL of 16 mg/kg but not the SEL of 75 mg/kg. However, nickel concentrations do not exceed the MOECC background level of 31 mg/kg [E-3]. As such nickel is not considered a COPC.

Phosphorous was detected at concentrations up to 787 mg/kg which exceeds the MOECC LEL of 600 mg/kg but not the SEL of 2000 mg/kg. However, phosphorous was identified below background concentrations identified in the Southern Ontario Stream Sediment Geochemistry Survey [E-6], as provided by the MNDM. Therefore phosphorous is not considered a COPC.

Silicon is a basic nutrient in sediment and is observed naturally from the breakdown of silicate minerals in the process of weathering. Large amounts of silicon are present in surface water and sediment. Therefore Total Silicon is not considered a COPC and will not be assessed further.

Elevated concentrations of sodium have been measured in the on-site sediment. These appear to be site related and may be due to road salting activities. Therefore sodium is considered a COPC.

Strontium concentrations in sediment ranged from 85.2 mg/kg to 1050 mg/kg. Concentrations in samples used to represent background are 281 mg/kg. Concentrations greater than background were identified at SRD-1 (1050 mg/kg), SRD-4 (489 mg/kg) and WD-4 (774 mg/kg). Based on the data, strontium is considered a COPC.

Thallium concentrations in sediment ranged from 0.063 mg/kg to 0.222 mg/kg. Concentrations in samples used to represent background had a 98th percentile concentration of 0.16 mg/kg. Concentrations greater than background were identified at WD-4 (0.222 mg/kg). The maximum thallium concentration is still within a range that can be found naturally in the environment, and concentrations are not much greater than what has been used to represent background. Thallium has not been identified as a COPC in soil or surface water. Thallium is therefore not considered a COPC and will not be addressed further.

Tin was identified at one sampling location at a concentration greater than the background value of 1 mg/kg. However, given that the maximum concentrations are not outside of the range of tin concentrations that are found in background sediments [E-6] and that inorganic tin has low toxicity [E-7], tin is not considered a COPC.

Titanium concentrations in sediment ranged from 95.3 mg/kg to 407 mg/kg. Concentrations in samples used to represent background had a 98th percentile concentration of 307 mg/kg. Concentrations greater than 307 mg/kg were identified at Locations C, D, and E. The maximum titanium concentration of 407 mg/kg is still within a range that can be found naturally in the environment. Titanium has not been identified as a COPC in soil or surface water and is not considered a COPC.

Tungsten concentrations in sediment ranged from 0.073 mg/kg to 0.391 mg/kg. Concentrations in samples used to represent background had a 98th percentile concentration of 0.1 mg/kg. Concentrations greater than background were identified at SRD-1 (0.279 mg/kg), SRD-4 (0.332 mg/kg), WD-4 (0.391 mg/kg) and WTL-1 (0.153 mg/kg). Based on the data, tungsten is considered a COPC.

E.2 SEDIMENT ECOLOGICAL BENCHMARKS

ARCS NEC [E-8]

US EPA ARCS Program. The representative effect concentration selected from among the high no-effect-concentrations for *Hyalella azteca* and *Chironomus riparius* are presented in [E-8]. It is a concentration above which statistically significant adverse biological effects always occur. Effects may occur below these levels. The majority of the data are for freshwater sediments.

ARCS PEC [E-8]

US EPA ARCS Program. The representative effect concentration selected from among the Effect Range Median (ER-Ms) and PELs for *Hyalella azteca* and *Chironomus riparius* are presented in [E-8]. The PEC is the geometric mean of the 50th percentile in the effects data set and the 85th percentile in the no effects data set. It represents the lower limit of the range of concentrations usually associated with adverse effects. A concentration greater than the PEC is likely to result in adverse effects to these organisms. The majority of the data are for freshwater sediments. These are probable-effects benchmarks.

ARCS TEC [E-8]

US EPA ARCS Program. The representative effect concentration selected from among the Effect Range Low (ER-Ls) and Threshold Effect Level (TELs) for *Hyalella azteca* and *Chironomus riparius* are presented in [E-8]. The TEC is the geometric mean of the 15th percentile in the effects data set and the 50th percentile in the no effects data set. It is a concentration that represents the upper limit of the range dominated by no effects data. Concentrations above the TEC may result in adverse effects to these organisms; concentrations below the TEC are unlikely to result in adverse effects. The majority of the data are for freshwater sediments. These are possible-effects benchmarks.

CNSC LEL and SEL [E-9]

The CNSC used sediment chemistry and benthic invertebrate community monitoring data for abundance and species richness from uranium mine sites in northern Saskatchewan and northern Ontario collected between 1985 and 2001. The LEL represents the contaminant concentration below which harmful effects on benthic invertebrates are not expected. The SEL represents the concentration above which harmful effects to most benthic invertebrates are expected.

Canadian Sediment Quality Guidelines (ISQG and PEL) [E-4]

The Water Quality Guidelines Task Group of the Canadian Council of Ministers of the Environment (CCME) developed chemical concentrations recommended to support and maintain aquatic life associated with bed sediments. These values are derived from available scientific information on biological effects of sediment-associated chemicals and are intended to support the functioning of healthy ecosystems. The Sediment quality guidelines protocol relies on the National Status and Trends Program approach and the Spiked-Sediment Toxicity Test approach.

The CCME provides an ISQG and a PEL concentration which results in three ranges for the evaluation of parameter concentrations in sediment:

1. If contaminant concentrations in sediment are less than the ISQG, then adverse biological effects are rare;
2. If contaminant concentrations in sediment are greater than the ISQG but are less than the PEL, adverse biological effects occur occasionally; and,
3. If contaminant concentrations in sediment are greater than the PEL, adverse biological effects are frequent.

The CCME ISQGs provide a nationally consistent benchmark; however, during implementation, exceedances of ISQGs must be evaluated in the context of naturally occurring background concentrations and in the context of site conditions, including physiochemical and geochemical factors. Concerns associated with contaminant concentrations in sediment must be focused on those non-radiological parameters with concentrations greater than what is expected to occur naturally.

Consensus PEC [E-10]

Consensus-based SQGs represent the geometric mean of published SQGs from a variety of sources with origins in Canada and the US. Combining several sets of guidelines into one to yield "consensus-based" guidelines have shown that such guidelines can substantially increase the reliability, predictive ability, and level of confidence in using and applying the guidelines. Sources for PECs include probable effect levels (i.e., PEL as used by the CCME), effect range median values, severe effect levels (i.e., SEL as used by the MOE, and toxic effect thresholds). PECs are intended to identify contaminant concentrations above which harmful effects on sediment-dwelling organisms are expected to occur more often than not.

Consensus TEC [E-10]

Consensus-based SQGs represent the geometric mean of published SQGs from a variety of sources with origins in Canada and the US. Combining several sets of guidelines into one to yield "consensus-based" guidelines have shown that such guidelines can substantially increase the reliability, predictive ability, and level of confidence in using and applying the guidelines. Sources for TECs include threshold effect levels, effect range low values, lowest effect levels, minimal effect thresholds, chronic equilibrium partitioning thresholds and threshold effect levels for *Hyalella azteca*. TECs are intended to identify contaminant concentrations below which harmful effects on sediment-dwelling organisms are not expected.

US EPA Region 3 BTAG Freshwater Sediment Screening Benchmarks [E-11]

US EPA Region 3 is responsible for executing the US EPA programs in Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia. The Region 3 BTAG Freshwater Sediment Screening Benchmarks are values to be used for the evaluation of sampling data at Superfund sites (i.e., abandoned hazardous waste properties addressed under the US EPA Superfund program).These values facilitate consistency in screening level ecological risk assessments throughout US EPA Region 3. Additional toxicological information should be considered in Step 3 as provided by the Ecological Risk Assessment Guidance for Superfund. The tables include compounds for which benchmark values have been established or that are considered bioaccumulative compounds (identified in tables).

US EPA Region 4 Waste Management Division Sediment Screening Values for Hazardous Waste Sites [E-12]

US EPA Region 4 is responsible for executing the US EPA programs in Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee and 6 Tribes. Sediment screening values are derived from statistical interpretation of effects databases obtained from the literature as reported in publications from the State of Florida, the National Oceanic and Atmospheric Administration, and a joint publication by Long et al [E-43]. These values are generally based on observations of direct toxicity. The US EPA Region 4 sediment screening values are the higher of the EPA Contract Laboratory Program Practical Quantitation Limit (PQL) and the Effects Value (i.e., the lower of the ER-L and the TEL which are marine sediment values). The values are considered as possible effects benchmarks. When the Contract Laboratory Program's PQL is above the effect level the screening value defaults to the PQL. For those contaminants whose screening values are based on the PQL, data reported below the required quantification limit (e.g., J-flagged data) should be compared to the Effects Level number. Although the sediment screening values have been developed from a database containing information from studies conducted predominantly in marine environments, personal communication with the authors of the studies indicate that corresponding values being developed from a freshwater database are within a factor of three of the marine based numbers. The existing values will be used for freshwater sites until a separate freshwater screening value table is developed.

US EPA Region 5 Ecological Screening Levels (ESLs) - Sediment [E-13]

US EPA Region 5 is responsible for executing the US EPA programs in Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin and 35 Tribes. The ESL reference database consists of US EPA Region 5 sediment ESLs for Resource Conservation and Recovery Act (RCRA) Appendix IX hazardous constituents. The ESLs are initial screening levels with which the site contaminant concentrations can be compared. The ESLs help to focus the investigation on those areas and chemicals that are most likely to pose an unacceptable risk to the environment. ESLs also impact the data requirements for the planning and implementation of field investigations. ESLs alone are not intended to serve as cleanup levels.

US EPA Region 6 Ecological Screening Benchmarks - Freshwater Sediment [E-14]

US EPA Region 6 is responsible for executing the US EPA programs in Arkansas, Louisiana, New Mexico, Oklahoma, Texas and 66 Tribes. U.S. EPA Region 6 recommends use of benchmarks developed for the Texas Natural Resource Conservation Commission. These benchmarks are conservative screening level values intended to be protective of benthic biota. Values were compiled from a prioritized list of published values. The primary benchmarks are threshold effect concentrations (TECs), but the value for silver is the ER-L value and is a marine sediment value.

Ontario Ministry of Environment and Energy (MOEE) LEL and SEL [E-5]

The MOECC provides a LEL and a SEL for metals. The LEL is a "level of contamination that can be tolerated by the majority of the sediment-dwelling organisms". The SEL represents sediment concentrations that are "likely to affect the health of sediment-dwelling organisms".

Guideline levels established by the MOECC were developed using the Screening Level Concentration method which uses co-located sediment concentrations of a contaminant with the presence of invertebrate species. For a given species, the chemical concentration at locations in which the species is present is plotted in order. A 90th percentile is chosen as the species screening level concentration (SLC). This is considered to represent the high end of the tolerance range for the species.

The species SLC are then plotted in increasing concentration. The 5th percentile is calculated to represent the LEL and the 95th percentile becomes the SEL.

Washington SQV [E-15], [E-16]

The State of Washington Department of Ecology SQVs were developed using chemistry and bioassay data from regional databases for sediments and are based on the ability of chemical criteria to reliably predict toxicity to the benthic community. Freshwater sediment chemical criteria were developed using the Floating Percentile Method (FPM). FPM uses a multivariate statistical approach that repetitively reduces predictive errors among all chemicals at one time. False positives to predict toxicity and false negatives to detect toxicity are reduced. This method allows the chemical concentration to accurately predict toxicity. The sediment quality values were developed using the lowest FPM value set. Two levels of SQVs were developed, the Sediment Quality Standard (SQS) and CSL. Concentrations at or below the SQS are predicted to have no adverse effects on the benthic communities. The SQS is the long term sediment quality goal. It is the lower end of the range of chemical concentrations or biological effects level used to establish a sediment cleanup level. The CSL is used to identify sediment cleanup sites and is the maximum chemical concentration or biological effects level allowed as a sediment cleanup level.

E.3 BENTHIC INVERTEBRATE

Additional details are provided here to support the interpretation of the benthic invertebrate data, which include the following information:

- The taxonomic identification and references used;
- Additional information on the metrics used for interpreting the benthic invertebrate results; and ,
- Key habitat characteristics for the watercourses.

E.3.1 Taxonomic Identification and References

Table E-1: Benthic Macroinvertebrate Identification ([E-17]-[E-35])

Site	SRD-1	SRD-4	WD-4	GS-1	WTL-1
% Subsampled	**100**	**50**	**50**	**50**	**50**
TAXA LIST					
ANNELIDA:HIRUDINEA:					
ERPOBDELLIDAE:					
Erpobdella fervida				5	
GLOSSIPHONIIDAE:					
Placobdella ornata	1				
ANNELIDA:OLIGOCHAETA:					
LUMBRICIDAE:			2	12	1
LUMBRICULIDAE:					
Lumbriculus variegatus					4
NAIDIDAE:					
Dero					1
TUBIFICIDAE:					
Immature With Hairs	12			279	1
Immature Without Hairs		10			
CRUSTACEA:AMPHIPODA:					
CRANGONYCTIDAE:					
Crangonyx			5		3
GAMMARIDAE:					
Gammarus fasciatus	1		30		
CRUSTACEA:ISOPODA:					

Site	SRD-1	SRD-4	WD-4	GS-1	WTL-1
% Subsampled	**100**	**50**	**50**	**50**	**50**
ASELLIDAE:					
Caecidotea	12	75	248		89
INSECTA:					
COLEOPTERA:					
ELMIDAE:					
Dubiraphia quadrinotata		19	17		
Optiosevus fastiditus			9		
HALIPLIDAE:					
Haliplus	1			1	
DIPTERA:					
CERATOPOGONIDAE:					
Bezzia/Palpomyia			2		
Sphaeromias				2	
CHIRONOMIDAE: CHIRONOMINAE:					
Chironomus	72	3		1	7
Cryptochironomus		3			
Einfeldia	5	2		1	
Polypedilum				3	
Tanytarsus		1		2	1
CHIRONOMIDAE:ORTHOCLADIINAE:					
Corynoneura				1	
Parametriocnemus			1		
CHIRONOMIDAE:TANYPODINAE:					
Ablabesmyia	12			1	4
Paramerina			1		
Procladius	10	1			
SIMULIIDAE:					
Simulium			3		1
TABANIDAE:					
Chysops		2		2	
TIPULIDAE:					
Helius					1
Limonia		1			
Tipula			1		
LEPIDOPTERA:					
CRAMBIDAE (=PYRALIDAE)					
Synclita			3		
ODONATA:					
AESHNIDAE:					
Aeshna				1	
Boyeria vinosa			1		
MOLLUSCA:BIVALVIA:					
SPHAERIIDAE:					

Site	SRD-1	SRD-4	WD-4	GS-1	WTL-1
% Subsampled	**100**	**50**	**50**	**50**	**50**
Musculium lacustre					6
Musculium securis	17				
Pisidium		5	43	1	117
MOLLUSCA:GASTROPODA:					
LYMNAEIDAE:					
Stagnicola elodes				4	
PHYSIDAE:					
Physella gyrina				1	
PLANORBIDAE:					
Armiger crista					2
Gyraulus circumstriatus		1		25	68
Helisoma anceps	3				
NEMATODA:			1		
PLATYHELMINTHES:					
PLANARIIDAE:			16		
TOTAL TAXA	11	12	16	17	15
TOTAL NUMBERS	146	123	383	342	306

E.3.2 Benthic Invertebrate Metrics

The characteristics of habitats impose selective forces through a variety of biotic and abiotic factors; these factors affect the fitness of individual organisms by modifying their growth, survival and reproduction [E-36]. The two major selective forces are physical disturbance and adversity of the environment. The adversity-disturbance continuum has been used to predict the traits of species in different quadrants of the habitat template, emergent properties of ecological communities, and in the classification of terrestrial and aquatic habitats [E-37].

Southwood also postulated that life history strategies are selected not only by predictability of the environment and resources but also according to the presence of stressors such as chemical toxicants. Some species avoid competition by occupying marginal habitats where stressors are more prevalent, with adaptations allowing them to survive in a hostile environment termed adversity selection (A). At the low range of the adversity axis, interspecific competition occurs and, as a habitat becomes more adverse, less competition occurs [E-38]. K-selected species are the competitive species which dominate in favorable and stable environments, whereas r-selected species rapidly colonize unstable environments. The biological selection strategies are displayed on a habitat template in Figure E-1. Examples for the quadrants of the template are displayed in Table E-2.

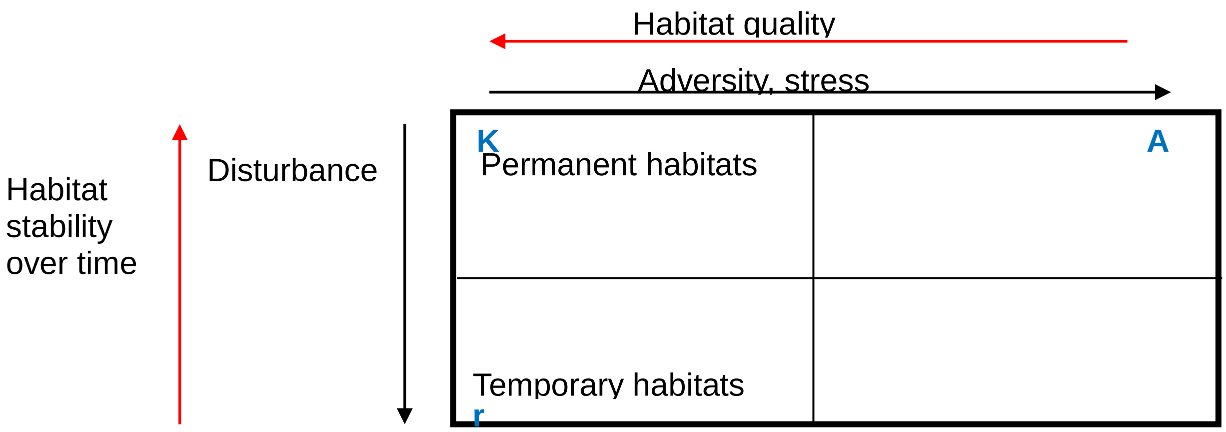

Figure E-1: Habitat Template with Biological Selection Strategy

Table E-2: Life History Traits for the Four Quadrants of the Habitat Template

	Categories	Low Adversity	High Adversity
Low Disturbance	Defence	high	medium
	Migration	low	low
	Offspring	few and large	medium and small
	Longevity	great	medium
	Example	crayfish	tubificids
High Disturbance	Defence	low	high
	Migration	high	high
	Offspring	many small	medium and large
	Longevity	small	medium
	Example	chironomid	mussels

Taxa proportion was calculated using the following equation:

$$P = Count/Total \qquad \text{(Equation 1.1)}$$

Where:

Count = the number of organisms from a specific taxa;

Total = the total number of organisms observed in the sample; and

P = proportion of a specific taxa.

Simpson's index of diversity is used to quantify the biodiversity of a community. It takes into account the number of species present and the abundance of each species. The diversity index ranges from 0 to 1 with 1 indicating high biodiversity. Simpson’s index of diversity was calculated per site using the following equation:

$$D=1-\sum_{i=1}^{s} P_i^2$$

(Equation 1.2)

Where:

D = Simpson’s index of diversity;

$\sum Pi^2$ = sum of the square proportions of each specific taxa.

S = the number of taxa observed at the sample location

Evenness refers to how similar in abundance each species is in an environment. Lower variation in species abundance among communities increases the index, and if species are equally abundant the index is 1. Evenness was calculated using the following equation:

$$E=\frac{1/\sum_{i=1}^{S} P_i^2}{S}$$

(Equation 1.3)

Where:

E = Evenness;

$\sum P$ = sum of the square proportion of each specific taxa at each site

S = the number of taxa observed at each site

Percent Ephemeroptera Plecoptera Trichoptera (EPT) (i.e., mayflies, stoneflies and caddis flies) and percent chironomids were also used as supporting descriptors of the benthic invertebrate communities sampled, as they are recognized as useful indices for characterization and comparison of benthic invertebrate communities. The EPT Index is the total number of distinct taxa within the groups, Trichoptera, Ephemeroptera, and Plecoptera. The EPT Index is the total number of distinct taxa within the groups, Trichoptera, Ephemeroptera, and Plecoptera. The signals provided by intolerant and tolerant taxa mean that the best expression of metrics based on these taxa differs between intolerants and tolerants [E-39]. The mere presence of very sensitive, or intolerant, taxa (as apparent from taxa richness) is a strong indicator of good biological condition; the relative abundance of these taxa, in contrast, is difficult to estimate accurately without extensive and costly sampling efforts [E-40]. Presence alone of tolerant taxa, on the other hand, says little about biological condition since tolerant groups inhabit a wide range of places and conditions, but as conditions deteriorate, their relative abundance rises [E-39].

The Hilsenhoff Biotic Index [E-41], [E-42] is commonly used to summarize benthic communities in stream environments based on known tolerances of organisms to organic pollution and anoxic environments. A benthic community classified as impaired

(HBI score between 8 and 10) or possibly impaired (HBI score between 6 and 8) is one that is made up predominantly of organisms that are tolerant of organic pollution, while a community classified as unimpaired is dominated by organisms that are sensitive to organic pollution (HBI score between 1 and 6). It was indicated that the Hilsenhoff index may be applicable to detecting non-organic pollution effects [E-40].

The HBI is presented is calculated using the following equation:

$$HBI = \frac{\sum_{i=1}^{S} Ct_i \times T_i}{S}$$

(Equation 1.4)

Where:

HBI = Hilsenhoff biotic index

Ct_i = count of taxa

T_i = tolerance of taxa

S = total number of organisms at the Sample station

Tolerance values used in the calculations are benthic family specific values as provided by [E-42]. Tolerance values range from 0 to 10, with 0 being the most sensitive benthic families and 10 being the most tolerant benthic families. Hilsenhoff identified tolerance values and the HBI as reflecting the tolerance of organisms to organic pollution and anoxic environments. The US EPA [E-40] has indicated that the Hilsenhoff index may also be applicable to evaluating non-organic pollution effects. Tolerance values from 0 to 2 indicate sensitivity to organic pollution, from 4 to 6 indicate moderately sensitive to organic pollution and 8 to 10 indicate tolerant of organic pollution.

Karr and Chu [E-39] suggest indicators for trophic structure and sensitivity to anthropogenic sources for interpretation of biological effects at the ecosystem scale. Trophic levels are assigned to the taxa observed in the benthic community assessment. The major functional feeding groups for macroinvertebrates are:

1. Scrapers/grazers which consume algae and associated material;
2. Shredders, which consume leaf litter or other Coarse Particulate Organic Matter, including wood;
3. Collector-gatherers, which collect Fine Particulate Organic Matter from the stream bottom;
4. Omnivores, which feed on both plants and animals;
5. Scavengers, which feeds on dead animal and plant material;
6. Parasites, which feed off a host organism;
7. Collectors-filterers, which collect Fine Particulate Organic Matter from the water column using a variety of filters; and,
8. Predators, which feed on other consumers.

The feeding habitats of the benthic invertebrates are utilized in a qualitative discussion of the trophic levels and feeding guilds at each sample station. Predominance of a particular feeding type may indicate an unbalanced community responding to an overburden of a particular food source [E-40]. Examples of feeding guild dominance which may reflect an unbalanced community discussed by the US EPA [E-40] are:

- Scrapers compared to collectors-filterers;
- Shredders compared to total individuals; and
- Dominance of particular feeding groups (e.g. 90% parasites).

E.3.3 Habitat Characteristics of Water Features

Table E-3: Key Habitat Characteristics of WWMF Water Features

Watercourse	Site ID	Month	Date Surveyed (dd/mm/yy)	Bankfull Width (m)	Average Bankfull Depth (m)	Active Channel Wetted Width (m)	Average Channel Wetted Depth (m)	Hydraulic Head	Channel Morphology (% composition)	Channel Depth (% of depth ranges)	Substrate Composition (%)	Maximum Particle Size Throughout Reach (%)	Maximum Particle Throughout Reach (mm)	Bank Stability	Instream Cover (% of surface area)	Instream Cover Types	Instream Aquatic Vegetation	Riparian Vegetation	Migratory Obstructions / Potential Critical Habitat	Upwelling's
South Railway Ditch	SRD-1	June	06/06/14	4.05	0.43	3.84	0.39	100% 0 to 3 mm	100% Pool/Flat	10% - 0 to 100 mm 80% - 101 to 600 mm 10% - 601 to 1000 mm	96% Fines 4% Gravel	92% Fines 8% Gravel	42	80% Eroding Bank (1) 10% Vulnerable Bank (2) 10% Deposition Zone (4)	96%	4% Wood 96% Macrophytes	95% Cattail 5% Water Milfoil	10% Grasses 10% Shrubs 70% Trees 10% Ferns	None Observed	None Observed
South Railway Ditch	SRD-1	July	17/07/14	4.20	0.60	4.01	0.56	100% 0 to 3 mm	100% Pool/Flat	80% - 101 to 600 mm 20% - 601 to 1000 mm	96% Fines 2% Gravel 2% Cobble	80% Fines 12% Gravel 8% Cobble	101	80% Eroding Bank (1) 10% Vulnerable Bank (2) 10% Deposition Zone (4)	100%	4% Round Rock 96% Macrophytes	95% Cattail 5% Water Milfoil	10% Grasses 10% Shrubs 70% Trees 10% Ferns	None Observed	None Observed
South Railway Ditch	SRD-1	October	21/10/14	4.14	0.49	4.14	0.49	100% 0 to 3 mm	100% Pool/Flat	80% - 101 to 600 mm 20% - 601 to 1000 mm	96% Fines 2% Gravel 2% Cobble	96% Fines 2% Gravel 2% Cobble	132	80% Eroding Bank (1) 10% Vulnerable Bank (2) 10% Deposition Zone (4)	100%	4% Round Rock 96% Macrophytes	95% Cattail 5% Water Milfoil	10% Grasses 10% Shrubs 70% Trees 10% Ferns	None Observed	None Observed
South Railway Ditch	SRD-2	June	06/06/14	4.25	0.19	3.75	0.06	100% 0 to 3 mm	100% Pool/Flat	50% - 0 to 100 mm 42% - 101 to 600 mm 8% - 601 to 1000 mm	100% Fines	96% Fines 4% Gravel	108	47% Eroding Bank (1) 33% Protected Bank (3) 13% Deposition Zone (4)	100%	100% Macrophytes	80% Cattail 20% Water Milfoil	5% Grasses 5% Sedges 25% Shrubs 50% Trees 15% Ferns	None Observed	None Observed
South Railway Ditch	SRD-2	June	17/07/14	4.25	0.19	3.93	0.10	100% 0 to 3 mm	100% Pool/Flat	64% - 0 to 100 mm 36% - 101 to 600 mm	100% Fines	89% Fines 11% Gravel	150	50% Eroding Bank (1) 29% Protected Bank (3) 21% Deposition Zone (4)	100%	100% Macrophytes	80% Cattail 20% Water Milfoil	5% Grasses 5% Sedges 25% Shrubs 50% Trees 15% Ferns	None Observed	None Observed
South Railway Ditch	SRD-2	October	20/10/14	4.25	0.16	3.99	0.14	100% 0 to 3 mm	100% Pool/Flat	54% - 0 to 100 mm 43% - 101 to 600 mm 3% - 601 to 1000 mm	97% Fines 2% Gravel 1%Cobble	97% Fines 2% Gravel 1%Cobble	170	50% Eroding Bank (1) 29% Protected Bank (3) 21% Deposition Zone (4)	96%	96% Macrophytes	85% Cattail 15% Water Milfoil	5% Grasses 5% Sedges 25% Shrubs 50% Trees 15% Ferns	None Observed	None Observed
South Railway Ditch	SRD-3	June	05/06/14	4.45	0.41	2.28	0.23	100% 0 to 3 mm	100% Pool/Flat	100% - 101 to 600 mm	98% Fines 2% Gravel	92% Fines 8% Gravel	80	90% Eroding Bank (1) 10% Protected Bank (3)	100%	90% Macrophytes 10% Wood	100% Cattail	10% Grasses 30% Shrubs 20% Trees 40% Ferns	None Observed	None Observed
South Railway Ditch	SRD-3	July	17/07/14	4.45	0.58	2.45	0.29	100% 0 to 3 mm	100% Pool/Flat	4% - 0 to 100 mm 96% - 101 to 600 mm	96% Fines 4% Gravel	84% Fines 16% Gravel	120	90% Eroding Bank (1) 10% Protected Bank (3)	96%	4% Flat Rock 4% Round Rock 92% Macrophytes	100% Cattail	10% Grasses 20% Shrubs 30% Trees 40% Ferns	None Observed	None Observed
South Railway Ditch	SRD-3	October	20/10/14	3.50	0.58	2.64	0.31	100% 0 to 3 mm	100% Pool/Flat	100% - 101 to 600 mm	96% Fines 4% Gravel	84% Fines 16% Gravel	140	90% Eroding Bank (1) 10% Protected Bank (3)	100%	4% Flat Rock 4% Round Rock 92% Macrophytes	100% Cattail	10% Grasses 20% Shrubs 30% Trees 40% Ferns	None Observed	None Observed
South Railway Ditch	SRD-4	June	06/06/14	4.21	0.16	0.79	0.11	100% 0 to 3 mm	100% Pool/Flat	40% - 0 to 100 mm 60% - 101 to 600 mm	100% Fines	100% Fines	1	80% Eroding Bank (1) 10% Vulnerable Bank (2) 10% Deposition Zone (4)	100%	4% Wood 96% Macrophytes	95% Cattail 5% Water Milfoil	10% Grasses 10% Shrubs 70% Trees 10% Ferns	None Observed	None Observed
South Railway Ditch	SRD-4	July	17/07/14	4.15	0.15	1.01	0.13	100% 0 to 3 mm	100% Pool/Flat	10% - 0 to 100 mm 90% - 101 to 600 mm	100% Fines	100% Fines	1	80% Eroding Bank (1) 10% Vulnerable Bank (2) 10% Deposition Zone (4)	100%	16% Wood 84% Macrophytes	95% Cattail 5% Water Milfoil	10% Grasses 10% Sedges 10% Shrubs 60% Trees 10% Ferns	None Observed	None Observed
South Railway Ditch	SRD-4	October	20/10/14	3.95	0.16	1.20	0.17	100% 0 to 3 mm	100% Pool/Flat	100% - 101 to 600 mm	100% Fines	100% Fines	2	80% Eroding Bank (1) 10% Vulnerable Bank (2) 10% Deposition Zone (4)	100%	91% Macrophytes 9% Bank	95% Cattail 5% Water Milfoil	10% Grasses 10% Sedges 10% Shrubs 60% Trees 10% Ferns	None Observed	None Observed
South Railway Ditch	SRD-5	June	06/06/14	0.62	0.13	0.46	0.08	100% 0 to 3 mm	100% Pool/Flat	44% - 0 to 100 mm 56% - 101 to 600 mm	50% Fines 50% Gravel	33% Fines 55% Gravel 12% Cobble	120	37% Eroding Bank (1) 13% Protected Bank (3) 30% Deposition Zone (4)	100%	9% Flat Rock 9% Round Rock 82% Macrophytes	100% Cattail	20% Grasses 45% Sedges 10% Shrubs 20% Trees 5% Ferns	None Observed	None Observed
South Railway Ditch	SRD-5	July	17/07/14	0.82	0.22	0.59	0.11	95% - 0 to 3 mm 5% - 4 to 7 mm	95% Pool/Flat 5% Glide	39% - 0 to 100 mm 61% - 101 to 600 mm	56% Fines 38% Gravel 6% Cobble	33% Fines 44% Gravel 23% Cobble	105	37% Eroding Bank (1) 13% Protected Bank (3) 30% Deposition Zone (4)	100%	18% Flat Rock 15% Round Rock 67% Macrophytes	100% Cattail	20% Grasses 45% Sedges 10% Shrubs 20% Trees 5% Ferns	None Observed	None Observed
South Railway Ditch	SRD-5	October	20/10/14	0.82	0.21	0.65	0.15	94% - 0 to 3 mm 6% - 4 to 7 mm	94% - Pool/Flat 6% - Glide	28% - 0 to 100 mm 72% - 101 to 600 mm	51% Fines 45% Gravel 4% Cobble	39% Fines 44% Gravel 17% Cobble	130	37% Eroding Bank (1) 13% Protected Bank (3) 30% Deposition Zone (4)	100%	10% Flat Rock 21% Rock 62% Macrophytes 7% Bank	100% Cattail	20% Grasses 45% Sedges 10% Shrubs 20% Trees 5% Ferns	None Observed	None Observed
West Ditch	WD-1	June	06/06/14	3.80	0.15	2.20	0.05	100% 0 to 3 mm	100% Pool/Flat	27% - 0 to 100 mm 73% - 101 to 600 mm	100% Fines	100% Fines	70	20% Eroding Bank (1) 10% Protected Bank (3) 70% Deposition Zone (4)	87%	100% Macrophytes	95% Cattail 5% Muskgrass	60% Grasses 5% Sedges 5% Shrubs 25% Trees 5% Ferns	None Observed	None Observed
West Ditch	WD-1	July	17/07/14	3.85	0.18	1.07	0.15	100% 0 to 3 mm	100% Pool/Flat	33% - 0 to 100 mm 67% - 101 to 600 mm	100% Fines	100% Fines	2	20% Eroding Bank (1) 10% Protected Bank (3) 70% Deposition Zone (4)	100%	88% Macrophytes 12% Debris	70% Cattail 10% Muskgrass 20% Needle Spike Grass	60% Grasses 5% Sedges 5% Shrubs 25% Trees 5% Ferns	None Observed	None Observed
West Ditch	WD-1	October	21/10/14	3.85	0.20	3.01	0.11	100% 0 to 3 mm	100% Pool/Flat	20% - 0 to 100 mm 80% - 101 to 600 mm	96% Fines 4% Gravel	80% Fines 20% Gravel	170	20% Eroding Bank (1) 10% Protected Bank (3) 70% Deposition Zone (4)	100%	100% Macrophytes	70% Cattail 10% Muskgrass 20% Needle Spike Grass	60% Grasses 5% Sedges 5% Shrubs 25% Trees 5% Ferns	None Observed	None Observed
West Ditch	WD-2	June	06/06/14	2.60	0.31	2.09	0.24	100% 0 to 3 mm	100% Pool/Flat	25% - 0 to 100 mm 75% - 101 to 600 mm	100% Fines	85% Fines 10% Gravel 5% Cobble	105	40% Eroding Bank (1) 40% Vulnerable Bank (3) 20% Deposition Zone (4)	75%	12% Flat Rock 5% Round Rock 83% Macrophytes	70% Cattail 20% Muskgrass 20% Softstem Bulrush	5% Grasses 5% Sedges 30% Shrubs 60% Trees	None Observed	None Observed
West Ditch	WD-2	July	18/07/14	2.65	0.36	2.15	0.33	100% 0 to 3 mm	100% Pool/Flat	20% - 0 to 100 mm 80% - 101 to 600 mm	100% Fines	80% Fines 20% Gravel	60	40% Eroding Bank (1) 40% Vulnerable Bank (3) 20% Deposition Zone (4)	100%	100% Macrophytes	60% Cattail 20% Muskgrass 20% Softstem Bulrush	5% Grasses 5% Sedges 30% Shrubs 60% Trees	None Observed	None Observed
West Ditch	WD-2	October	21/10/14	2.65	0.28	2.30	0.24	100% 0 to 3 mm	100% Pool/Flat	20% - 0 to 100 mm 80% - 101 to 600 mm	95% Fines 5% Gravel	80% Fines 15% Gravel 5% Cobble	120	40% Eroding Bank (1) 40% Vulnerable Bank (3) 20% Deposition Zone (4)	100%	5% Wood 95% Macrophytes	60% Cattail 20% Muskgrass 20% Softstem Bulrush	5% Grasses 5% Sedges 30% Shrubs 60% Trees	None Observed	None Observed

Watercourse	Site ID	Month	Date Surveyed (dd/mm/yy)	Bankfull Width (m)	Average Bankfull Depth (m)	Active Channel Wetted Width (m)	Average Channel Wetted Depth (m)	Hydraulic Head	Channel Morphology (% composition)	Channel Depth (% of depth ranges)	Substrate Composition (%)	Maximum Particle Size Throughout Reach (%)	Maximum Particle Throughout Reach (mm)	Bank Stability	Instream Cover (% of surface area)	Instream Cover Types	Instream Aquatic Vegetation	Riparian Vegetation	Migratory Obstructions / Potential Critical Habitat	Upwelling's
West Ditch	WD-3	June	06/06/14	6.26	0.26	1.80	0.07	87% - 0 to 3 mm 7% - 4 to 7 mm 6% - 8 to 17 mm	87% Pool/Flat 7% Glide 6% Slow Riffle	60% - 0 to 100 mm 40% - 101 to 600 mm	30% Fines 70% Gravel	20% Fines 73% Gravel 5% Cobble	125	40% Vulnerable Bank (2) 60% Deposition Zone (4)	100%	20% Flat Rock 10% Wood 70% Macrophytes	90% Cattail 10% Pondweed	30% Grasses 10% Sedges 10% Shrubs 40% Trees 10% Ferns	None Observed	None Observed
West Ditch	WD-3	July	18/07/14	6.40	0.19	1.56	0.08	66% - 0 to 3 mm 34% - 4 to 7 mm	66% Pool/Flat 34% Glide	66% - 0 to 100 mm 34% - 101 to 600 mm	32% Fines 66% Gravel 2% Cobble	13% Fines 80% Gravel 7% Cobble	80	40% Vulnerable Bank (2) 60% Deposition Zone (4)	100%	28% Flat Rock 10% Wood 62% Macrophytes	90% Cattail 10% Pondweed	20% Grasses 20% Sedges 10% Shrubs 40% Trees 10% Ferns	None Observed	None Observed
West Ditch	WD-3	October	21/10/14	6.10	0.16	2.26	0.08	60% - 0 to 3 mm 20% - 4 to 7 mm 20% - 8 to 17 mm	60% Pool/Flat 20% Glide 20% Slow Riffle	47% - 0 to 100 mm 53% - 101 to 600 mm	10% Fines 84% Gravel 6% Cobble	13% Fines 80% Gravel 7% Cobble	90	40% Vulnerable Bank (2) 60% Deposition Zone (4)	100%	26% Flat Rock 74% Macrophytes	90% Cattail 10% Pondweed	20% Grasses 20% Sedges 10% Shrubs 40% Trees 10% Ferns	None Observed	None Observed
West Ditch	WD-4	June	06/06/14	3.60	0.80	1.40	0.44	85% - 0 to 3 mm 15% - 4 to 7 mm	81% Pool/Flat 19% Glide	70% - 0 to 100 mm 30% - 101 to 600 mm	42% Fines 18% Gravel 40% Cobble	35% Fines 20% Gravel 55% Cobble	160	100% Protected Bank (3)	93%	33% Flat Rock 20% Wood 47% Macrophytes	80% Cattail 20% Watercress	20% Shrubs 80% Trees	None Observed	None Observed
West Ditch	WD-4	July	18/07/14	3.46	0.55	1.15	0.13	81% - 0 to 3 mm 19% - 4 to 7 mm	81% Pool/Flat 19% Glide	81% - 0 to 100 mm 19% - 101 to 600 mm	32% Fines 17% Gravel 51% Cobble	15% Fines 18% Gravel 67% Cobble	125	100% Protected Bank (3)	94%	33% Flat Rock 14% Rock 10% Wood 43% Macrophytes	80% Cattail 20% Watercress	30% Shrubs 70% Trees	None Observed	None Observed
West Ditch	WD-4	October	21/10/14	3.30	0.49	1.72	0.17	74% - 0 to 3 mm 26% - 4 to 7 mm	74% Pool/Flat 26% Glide	33% - 0 to 100 mm 67% - 101 to 600 mm	31% Fines 20% Gravel 49% Cobble	26% Fines 30% Gravel 44% Cobble	130	100% Protected Bank (3)	96%	37% Flat Rock 20% Wood 43% Macrophytes	80% Cattail 20% Watercress	30% Shrubs 70% Trees	None Observed	None Observed
Grassed Swale	GS-1	June	06/06/14	N/A	N/A	N/A	0.13	100% 0 to 3 mm	19% Glide	40% - 0 to 100 mm 60% - 101 to 600 mm	90% Fines 10% Gravel	90% Fines 10% Gravel	60	N/A	60%	100% Macrophytes	15% Cattail 10% Algae 55% Water Arum 20% Pondweed	30% Grasses 30% Sedges 15% Shrubs 20% Trees 5% Ferns	None Observed	None Observed
Grassed Swale	GS-1	July	18/07/14	N/A	N/A	N/A	0.11	100% 0 to 3 mm	100% Pool/Flat	40% - 0 to 100 mm 60% - 101 to 600 mm	90% Fines 10% Gravel	90% Fines 10% Gravel	70	N/A	60%	100% Macrophytes	15% Cattail 10% Algae 55% Water Arum 20% Pondweed	55% Grasses 20% Sedges 5% Shrubs 20% Trees	None Observed	None Observed
Grassed Swale	GS-1	October	21/10/14	N/A	N/A	N/A	0.14	100% 0 to 3 mm	100% Pool/Flat	30% - 0 to 100 mm 70% - 101 to 600 mm	90% Fines 10% Gravel	85% Fines 15% Gravel	60	N/A	60%	100% Macrophytes	15% Cattail 10% Algae 55% Water Arum 20% Pondweed	55% Grasses 20% Sedges 5% Shrubs 20% Trees	None Observed	None Observed
Wetland	WTL-1	June	06/06/14	N/A	N/A	N/A	0.19	100% 0 to 3 mm	100% Pool/Flat	50% - 0 to 100 mm 50% - 101 to 600 mm	95% Root Mass 5% Fines	95% Root Mass 5% Fines	4	N/A	98%	10% Wood 90% Macrophytes	100% Cattail	30% Grasses 30% Sedges 30% Shrubs 10% Trees	None Observed	None Observed
Wetland	WTL-1	July	18/07/14	N/A	N/A	N/A	0.11	100% 0 to 3 mm	100% Pool/Flat	50% - 0 to 100 mm 50% - 101 to 600 mm	95% Root Mass 5% Fines	95% Root Mass 5% Fines	4	N/A	98%	10% Wood 90% Macrophytes	100% Cattail	60% Grasses 15% Sedges 15% Shrubs 10% Trees	None Observed	None Observed
Wetland	WTL-1	October	21/10/14	N/A	N/A	N/A	0.24	100% 0 to 3 mm	100% Pool/Flat	50% - 0 to 100 mm 50% - 101 to 600 mm	95% Root Mass 5% Fines	95% Root Mass 5% Fines	4	N/A	98%	10% Wood 90% Macrophytes	100% Cattail	60% Grasses 15% Sedges 15% Shrubs 10% Trees	None Observed	None Observed

Notes

N/A Non Applicable
1 Angle >45°, erodible soil, undercut or bare soil.
2 Angle >45°, erodible soil, no sign of recent erosion.
3 Angle >45°, non-erodible material/soil.
4 Angle <45°, (gradual slope from river), fine grained sediments

Table E-4: Sediment Quality Laboratory Analysis for Total Organic Carbon

Location		WWMF	WWMF	WWMF	WWMF	WWMF	WWMF	WWMF	WWMF	WWMF	WWMF
Sample ID		SRD-1 Average	SRD-4	GS-1	WTL-1	WD-4 Average	SRD-1 Average	SRD-4	GS-1 Average	WTL-1	WD-4
Sampling Date (MM/DD/YY)		04/16/14	04/17/14	04/16/14	04/16/14	04/17/14	10/15/14	10/15/14	10/15/14	10/15/14	10/15/14
Laboratory ID Number		VP3854	VP3855	VP3856	VP3857	VP3858	YB1766	YB1767	YB1768	YB1769	YB1770
	Units										
Total Organic Carbon	%	6.10	5.5	3.6	11	7.10	5.4	4	5.15	7	7.6

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Appendix F: Weight of Evidence Tables

Table F-1: Weight of Evidence Scoring

Receptor Group	Assessment Endpoint	Measurement Endpoints	Line of Evidence	Magnitude			Causality		Ecological Relevance
				Degree of contamination and effect size	Spatial Scale for evaluation of magnitude	Uncertainty about magnitude	Evidence for causality	Uncertainty about causality	
Benthic Invertebrates	Benthic Community Diversity	LOE 1A Sediment Chemistry	1A: Compare estimated exposure concentrations to benthic invertebrate toxicity values	Chemistry is characterized based on toxicity value	Analysis of proportion of samples across the Site exceeding toxicity values with consideration of the size of the water body	Subjective evaluation based on number of samples	Link between contamination and site related source	Subjective based on consideration of study design, sample sizes, and understanding of site characterization	Low/Moderate - comparison to toxicological values
				Low – Hazard Quotient (HQ) <1 Moderate - HQ > 1 and <2 High - HQ > 2	Low - 10% of area affected Moderate - 10 to 50% of area affected High - >50% of area affected	Low Moderate High	None - no source Weak - possible source Strong - source known	Low Moderate High	
		LOE 2A Benthic Community Analysis	2A: Qualitative Evaluation of Abundance and Diversity	Comparison of abundance and diversity based on spatial patterns	Analysis of spatial gradients over the area where the sampling occurs	Subjective evaluation based on number of samples and level or rigor in measures used	Subjective based on consideration of study design, sample sizes, and explanatory power and statistical significance	Subjective based on consideration of study design, sample sizes, and comparison to controls/reference conditions	High - qualitative evaluation based on field observations
				Low - no apparent effect Moderate - effect may be present High - clear association between chemistry and impact	Low - 10% of area affected Moderate - 10 to 50% of area affected High - >50% of area affected	Low Moderate High	None - no linkage between contamination and observed effect Weak - possible linkage between contamination and effect Strong - known linkage between contamination and effect	Low -identified reference area which is comparable habitat Moderate - identified reference area which does not have comparable habitat High -a reference area was not identified	

Table F-2: Weight of Evidence Evaluation – South Railway Ditch

Receptor Group	Assessment Endpoint	Measurement Endpoints	Line of Evidence	Magnitude			Causality		Ecological Relevance	Overall Assessment
				Degree of contamination and effect size	Spatial Scale for evaluation of magnitude	Uncertainty about magnitude	Evidence for causality	Uncertainty about causality		
Benthic Invertebrates	Benthic Community Diversity	LOE 1A Sediment Chemistry	1A: Compare estimated exposure concentrations to benthic invertebrate toxicity values	Chemistry is characterized based on toxicity value	Analysis of proportion of samples across the Site exceeding toxicity values	Subjective evaluation based on number of samples	Link between contamination and site related source	Subjective based on consideration of study design, sample sizes, and understanding of site characterization	Low/Moderate - comparison to toxicological values	Moderate effects with moderate uncertainty- sediment chemistry is greater than the selected effects benchmark for zinc. The benthic community assessment indicates moderate effects to richness and abundance of benthic invertebrates but a reference location was not available for comparison and uncertainty is high.
				Moderate (copper): > Consensus-Based PEC - HQ >1 and < 2 for SRD-1 Moderate (zinc): > Consensus-Based PEC - HQ >1 and < 2 for SRD-1/SRD-4 Low (silver, sodium, strontium, and tungsten) - HQ < 1	Moderate (copper and zinc): 25% to 50% of area affected seasonally Low (silver, sodium, strontium, and tungsten): no area affected	Moderate	Strong: Copper, strontium, sodium and zinc (upstream activities); Weak: Tungsten (upstream activities) Silver - not applicable as no sediment impacts	Low		
		LOE 2A Benthic Community Analysis	2A: Qualitative Evaluation of Abundance and Diversity	Comparison of abundance and diversity based on spatial patterns	Analysis of spatial gradients over the area where the sampling occurs	Subjective evaluation based on number of samples	Subjective based on consideration of study design, sample sizes, and comparison to controls/reference conditions	Subjective based on consideration of study design, sample sizes, and comparison to controls/reference conditions	High	
				Moderate - effect may be present	Moderate - 10 to 50% of area affected	Moderate -one set of samples was collected and statistics were not computed	Weak - zinc and copper are present at possible effect levels	High - a reference was not identified		

Table F-3: Weight of Evidence Evaluation – Wetland

Receptor Group	Assessment Endpoint	Measurement Endpoints	Line of Evidence	Magnitude			Causality		Ecological Relevance	Overall Assessment
				Degree of contamination and effect size	Spatial Scale for evaluation of magnitude	Uncertainty about magnitude	Evidence for causality	Uncertainty about causality		
Benthic Invertebrates	Benthic Community Diversity	LOE 1A Sediment Chemistry	1A: Compare estimated exposure concentrations to benthic invertebrate toxicity values	Chemistry is characterized based on toxicity value	Analysis of proportion of samples across the Site exceeding toxicity values	Subjective evaluation based on number of samples	Link between contamination and site related source	Subjective based on consideration of study design, sample sizes, and understanding of site characterization	Low/Moderate - comparison to toxicological values	Based on sediment chemistry, potential for adverse effects in association with the metals is low as all HQs are <1. The benthic community assessment indicates that there are some sensitive invertebrate families and even proportions of families. Uncertainty in the benthic assessment is high due to one sampling event and no reference location identified.
				Low - All HQs < 1	Low - no area affected	Moderate - two area of the Wetland sampled (i.e., GS-1 and WTL-1)	Strong: Sodium (stormwater runoff from site and road salting); Weak: Copper (construction landfill) Weak: Zinc (upstream activities, construction landfill and general industrial activities) None: Tungsten Silver and strontium - not applicable as no sediment impacts	Low		
		LOE 2A Benthic Community Analysis	2A: Qualitative Evaluation of Abundance and Diversity	Comparison of abundance and diversity based on spatial patterns	Analysis of spatial gradients over the area where the sampling occurs	Subjective evaluation based on number of samples	Subjective based on consideration of study design, sample sizes, and comparison to controls/reference conditions	Subjective based on consideration of study design, sample sizes, and comparison to controls/reference conditions	High - qualitative evaluation based on field observations	
				Low - no apparent effect	Low - 10% of area affected	Moderate -one set of samples was collected and statistics were not computed	None - No contaminants are at possible effect levels	High - a reference was not identified and areas of the Wetland have recently been disturbed.		

Table F-4: Weight of Evidence Evaluation – West Ditch

Receptor Group	Assessment Endpoint	Measurement Endpoints	Line of Evidence	Magnitude			Causality		Ecological Relevance	Overall Assessment
				Degree of contamination and effect size	**Spatial Scale for evaluation of magnitude**	**Uncertainty about magnitude**	**Evidence for causality**	**Uncertainty about causality**		
Benthic Invertebrates	Benthic Community Diversity	LOE 1A Sediment Chemistry	1A: Compare estimated exposure concentrations to benthic invertebrate toxicity values	Chemistry is characterized based on toxicity value	Analysis of proportion of samples across the Site exceeding toxicity values	Subjective evaluation based on number of samples	Link between contamination and site related source	Subjective based on consideration of study design, sample sizes, and understanding of site characterization	Low/Moderate - comparison to toxicological values	Silver has a high potential for effects with high uncertainty for spatial scale. The benthic community assessment does not indicate impairment and several organic pollution sensitive families are present in the West Ditch. However, the community displayed dominance of a single family (Asellidae). Uncertainty in the benthic assessment is high due to one sampling event and no reference location identified.
				High (silver): > - HQ > 9 for WD-4 (note that the selected TRV is a low effects value[1]) Low (copper, silver, sodium, strontium, tungsten, and zinc) - HQ < 1	High (silver): > 50% of area affected seasonally Low (copper, sodium, strontium, tungsten, and zinc): no area affected	High (silver): only one sampling location	Weak - industrial sources in the area; although specific source unknown	Moderate		
		LOE 2A Benthic Community Analysis	2A: Qualitative Evaluation of Abundance and Diversity	Comparison of abundance and diversity based on spatial patterns	Analysis of spatial gradients over the area where the sampling occurs	Subjective evaluation based on number of samples	Subjective based on consideration of study design, sample sizes, and comparison to controls/reference conditions	Subjective based on consideration of study design, sample sizes, and comparison to controls/reference conditions	High - qualitative evaluation based on field observations	
				Low - no apparent effect	High - >50% of area affected	Moderate -one set of samples were collected and statistics are not computed	Weak - Silver is above effects benchmarks in sediment.	High - a reference was not identified		

1. Silver TRV is the Washington SQV of 1.7 mg/kg.

Appendix G: Environmental Data Sets

Table G-1: Environmental Media Sampling Program: Baseline Enhancement Monitoring (2014 to 2015) and WWMF EMP (2013 to 2014)

Media	Location	Time of Sampling	Analyte(s) and/or Description
Baseline Enhancement Monitoring			
Soil Quality	A1-1 and A1-2 in Area 1, A2-1 and A2-1 in Area 2, A3-1 and A3-2 in Area 3, A4-1 and A4-2 in Area 4, SWALE in the GS, RD-1 and RD-2 in the SRD and MSA-1 along the SRD in the recharge area of the MSA.	June and August 2014	Shallow soil (0-15 cm depth below grade) PHC F1-F4, metals, and inorganics (including conductivity, SAR, pH, ICAP/hydride metals including Cr(VI) and Mn), VOC, dioxins and furans, moisture, and grain size
	North woodland, east of incinerator, and south of incinerator with 8 samples/location	June and August 2014	Shallow soil (0-15 cm below grade) and deep soil (15 to 20 cm below grade) Radionuclides (tritium, C-14, and gamma scan)
Vegetation - Cedar	North woodland, east of incinerator, and south of incinerator with 8 samples/location	February, June, August, and October, 2014	Radionuclides (tritium, C-14,and gamma scan)
- Other vegetation (Includes young shoots, mixtures of berries, acorns, grass and nuts)	North woodland, east of incinerator, and south of incinerator with 8 samples/location	June, August, and October, 2014	Radionuclides (tritium, C-14, and gamma scan)
Groundwater	WS-79100-US6, -WSH229, -WSH238, -WSH241, -WSH245, -WSH248, and -WSH250	February, May, June, August, and October, 2014	Tritium, gross beta, VOC, PHC (F1-F4), metals, inorganics, and hardness (CaCO3)
Surface Water	SRD-1, SRD-4, GS-	April, July, and	VOC, PHC (F1-F4), metals, total ammonia as N, un-ionized ammonia,

Media	Location	Time of Sampling	Analyte(s) and/or Description
Quality	1, WTL-1 and WD-4	October, 2014	total P, water temperature, COD, pH, conductivity, TDS, hardness, TOC, TSS, alkalinity, and dissolved Cl
	SRD-1, SRD-2, SRD-3, SRD-4, GS-1, WTL-1, WD-1, WD-2, WD-3 and WD-4	April, May, July, September, and October, 2014	Measured infield water quality while sampling other parameters: air and water temperature, pH, conductivity, TDS, DO, oxidation-reduction potential, water depth.
	SRD-1, SRD-4, GS-1, WTL-1 and WD-4	May andNovember, 2014	Measured TSS after storm events
Sediment Quality	SRD-1, SRD-4, GS-1, WTL-1 and WD-4	April and October, 2014	% moisture, TOC, pH, VOC, PHC (F1-F4), metals, and inorganics
Cattail Tissue	SRD-1, SRD-2, SRD-3, SRD-4, SRD-5, GS-1, WD-1, WD-2, WD-3 WD-4, and WTL-1	July 2014	Metals
WWMF EMP			
Surface Water Quality	Location A (SRD-1), Location B (between SRD-1 and SRD-2), Location C (SRD-2)	May, July, and October, 2013	Tritium
	Location C (SRD-2), Location E (SRD-3) and Location D (GS-1)	June and October, 2013, and May, 2014	Tritium, C-14, gamma scan, and metals
Sediment Quality	Location C (SRD-2), Location E (SRD-3) and Location D (GS-1)	June and October, 2013, and May, 2014	Gamma scan and metals. Radionuclides were only analysed for the June and May sediment samples.

Parameter	Medium	Units	Concentration			# of samples taken	Mass of max sample* (g)
			Maximum	Minimum	Standard Deviation		
Ag-110m	CEDAR	Bq/kg	<2.1	<2	N/A	27	NR
Ba-140	CEDAR	Bq/kg	<682	<120	N/A	27	NR
Be-7	CEDAR	Bq/kg	78.4	18.6	16.3	27	NR
C-14	CEDAR	Bq/kg-C	878	330	171.1	27	NR
Ce-141	CEDAR	Bq/kg	<13.8	<6	N/A	27	NR
Ce-144	CEDAR	Bq/kg	<11.9	<5	N/A	27	NR
Co-57	CEDAR	Bq/kg	<1.6	<1	N/A	27	NR
Co-58	CEDAR	Bq/kg	<3.7	<1	N/A	27	NR
Co-60	CEDAR	Bq/kg	<2.5	<1	N/A	27	NR
Cr-51	CEDAR	Bq/kg	<92.8	<27.2	N/A	27	NR
Cs-134	CEDAR	Bq/kg	<2.2	<1	N/A	27	NR
Cs-137	CEDAR	Bq/kg	<1.8	<1	N/A	27	NR
Eu-154	CEDAR	Bq/kg	<3	<3	N/A	27	NR
Eu-155	CEDAR	Bq/kg	<5.2	<2	N/A	27	NR
Fe-59	CEDAR	Bq/kg	<13.3	<2.5	N/A	27	NR
H-3	CEDAR	Bq/kg (HTO)	1240	473	279.3	27	NR
I-131	CEDAR	Bq/kg	2110	<338	N/A	27	NR
K-40	CEDAR	Bq/kg	95.6	47.2	12.9	27	NR
La-140	CEDAR	Bq/kg	<163	<27.1	N/A	27	NR
Mn-54	CEDAR	Bq/kg	<2.3	<1	N/A	27	NR
Nb-94	CEDAR	Bq/kg	<1.6	<1	N/A	27	NR
Nb-95	CEDAR	Bq/kg	<4.4	<1	N/A	27	NR
Ru-103	CEDAR	Bq/kg	<7.7	<1.8	N/A	27	NR
Ru-106	CEDAR	Bq/kg	<20.7	<10	N/A	27	NR
Sb-124	CEDAR	Bq/kg	8.5	<2	N/A	27	NR
Sb-125	CEDAR	Bq/kg	<4.5	<2	N/A	27	NR
Se-75	CEDAR	Bq/kg	<3	<1	N/A	27	NR
Th-series	CEDAR	Bq/kg	<6.6	<3	N/A	27	NR
U-series	CEDAR	Bq/kg	6.7	<3	1.2	27	NR
Zn-65	CEDAR	Bq/kg	<5.9	<3	N/A	27	NR
Zr-95	CEDAR	Bq/kg	<7.8	<2	N/A	27	NR

N/A - Not applicable

NR - Not required

*Sample mass used to convert concentrations from Bq/kg to Bq/m^2

Parameter	Medium	Units	Concentration			# of samples taken	Mass of max sample* (g)
			Maximum	Minimum	Standard Deviation		
Ag-110m	CEDAR	Bq/kg	<2	<2	N/A	24	NR
Ba-140	CEDAR	Bq/kg	<8.4	<5	N/A	24	NR
Be-7	CEDAR	Bq/kg	73	35	10.4	24	NR
C-14	CEDAR	Bq/kg-C	983	638.00	113.7	24	NR
Ce-141	CEDAR	Bq/kg	<2.3	<1	N/A	24	NR
Ce-144	CEDAR	Bq/kg	<9.4	<5	N/A	24	NR
Co-57	CEDAR	Bq/kg	<1.2	<1	N/A	24	NR
Co-58	CEDAR	Bq/kg	<1.2	<1	N/A	24	NR
Co-60	CEDAR	Bq/kg	<1.4	<1	N/A	24	NR
Cr-51	CEDAR	Bq/kg	<11.7	<10	N/A	24	NR
Cs-134	CEDAR	Bq/kg	<1.3	<1	N/A	24	NR
Cs-137	CEDAR	Bq/kg	<1.5	<1	N/A	24	NR
Eu-154	CEDAR	Bq/kg	<3	<3	N/A	24	NR
Eu-155	CEDAR	Bq/kg	<5	<2	N/A	24	NR
Fe-59	CEDAR	Bq/kg	<2.5	<2	N/A	24	NR
H-3	CEDAR	Bq/kg (HTO)	983	638	85.2	24	NR
I-131	CEDAR	Bq/kg	<3.1	<2	N/A	24	NR
K-40	CEDAR	Bq/kg	78	43.1	81.3	24	NR
La-140	CEDAR	Bq/kg	<2.1	<2	N/A	24	NR
Mn-54	CEDAR	Bq/kg	<1.4	<1	N/A	24	NR
Nb-94	CEDAR	Bq/kg	<1.3	<1	N/A	24	NR
Nb-95	CEDAR	Bq/kg	<1.2	<1	N/A	24	NR
Ru-103	CEDAR	Bq/kg	<1.3	<1	N/A	24	NR
Ru-106	CEDAR	Bq/kg	<11.7	<10	N/A	24	NR
Sb-124	CEDAR	Bq/kg	<3.2	<2	N/A	24	NR
Sb-125	CEDAR	Bq/kg	<3.3	<2	N/A	24	NR
Se-75	CEDAR	Bq/kg	<1.6	<1	N/A	24	NR
Th-series	CEDAR	Bq/kg	<4.2	<3	N/A	24	NR
U-series	CEDAR	Bq/kg	<3	<3	N/A	24	NR
Zn-65	CEDAR	Bq/kg	<3	<3	N/A	24	NR
Zr-95	CEDAR	Bq/kg	<2.3	<2	N/A	24	NR
Ag-110m	SOIL AT DEPTH	Bq/kg	<13.2	<2	N/A	24	NR

Parameter	Medium	Units	Concentration			# of samples taken	Mass of max sample* (g)
			Maximum	Minimum	Standard Deviation		
Ba-140	SOIL AT DEPTH	Bq/kg	<62.4	<5	N/A	24	NR
Be-7	SOIL AT DEPTH	Bq/kg	<16.5	<10	N/A	24	NR
C-14	SOIL AT DEPTH	Bq/kg-C	512	188.00	91.7	24	7.34
Ce-141	SOIL AT DEPTH	Bq/kg	<4.1	<1.3	N/A	24	NR
Ce-144	SOIL AT DEPTH	Bq/kg	<8.3	<5	N/A	24	NR
Co-57	SOIL AT DEPTH	Bq/kg	<1	<1	N/A	24	NR
Co-58	SOIL AT DEPTH	Bq/kg	<1.5	<1	N/A	24	NR
Co-60	SOIL AT DEPTH	Bq/kg	<1.4	<1	N/A	24	NR
Cr-51	SOIL AT DEPTH	Bq/kg	<27.4	<10	N/A	24	NR
Cs-134	SOIL AT DEPTH	Bq/kg	<1.3	<1	N/A	23	NR
Cs-137	SOIL AT DEPTH	Bq/kg	29.2	2.8	7.3	24	NR
Eu-154	SOIL AT DEPTH	Bq/kg	<3	<3	N/A	24	NR
Eu-155	SOIL AT DEPTH	Bq/kg	<3.9	<2	N/A	24	NR
Fe-59	SOIL AT DEPTH	Bq/kg	<5.6	<2	N/A	24	NR
H-3	SOIL AT DEPTH	Bq/kg (HTO)	512	188	98.2	24	NR
I-131	SOIL AT DEPTH	Bq/kg	<56.6	<2	N/A	24	NR
K-40	SOIL AT DEPTH	Bq/kg	455	260	44.7	24	NR
La-140	SOIL AT DEPTH	Bq/kg	<14.7	<2	N/A	24	NR
Mn-54	SOIL AT DEPTH	Bq/kg	<1	<1	N/A	24	NR
Nb-94	SOIL AT DEPTH	Bq/kg	<1	<1	N/A	24	NR
Nb-95	SOIL AT DEPTH	Bq/kg	<2.7	<1	N/A	24	NR
Ru-103	SOIL AT DEPTH	Bq/kg	<2.3	<1	N/A	24	NR
Ru-106	SOIL AT DEPTH	Bq/kg	<10	<10	N/A	24	NR
Sb-124	SOIL AT DEPTH	Bq/kg	<3.7	<2	N/A	24	NR
Sb-125	SOIL AT DEPTH	Bq/kg	<2.8	<2	N/A	24	NR
Se-75	SOIL AT DEPTH	Bq/kg	<1.7	<1	N/A	24	NR
Th-series	SOIL AT DEPTH	Bq/kg	15.6	8.1	2.1	24	NR
U-series	SOIL AT DEPTH	Bq/kg	36.1	12.1	3.4	24	NR
Zn-65	SOIL AT DEPTH	Bq/kg	<7.3	<3	N/A	24	NR
Zr-95	SOIL AT DEPTH	Bq/kg	<2.7	<2	N/A	24	NR
Ag-110m	SURFACE SOIL	Bq/kg	<19.8	<2	N/A	24	321
Ba-140	SURFACE SOIL	Bq/kg	<67.2	<6.7	N/A	24	333

Parameter	Medium	Units	Concentration			# of samples taken	Mass of max sample* (g)
			Maximum	Minimum	Standard Deviation		
Be-7	SURFACE SOIL	Bq/kg	<18.6	<10	N/A	24	321
C-14	SURFACE SOIL	Bq/kg-C	729	249.00	124.8	24	7.56
Ce-141	SURFACE SOIL	Bq/kg	<5.3	<2.2	N/A	24	437
Ce-144	SURFACE SOIL	Bq/kg	<15.1	<5.1	N/A	24	250
Co-57	SURFACE SOIL	Bq/kg	<1.8	<1	N/A	24	250
Co-58	SURFACE SOIL	Bq/kg	<1.7	<1	N/A	24	333
Co-60	SURFACE SOIL	Bq/kg	<2.1	<1	N/A	24	406
Cr-51	SURFACE SOIL	Bq/kg	<31	<11	N/A	24	437
Cs-134	SURFACE SOIL	Bq/kg	3	<1	N/A	23	498
Cs-137	SURFACE SOIL	Bq/kg	51.6	5.7	12.6	24	250
Eu-154	SURFACE SOIL	Bq/kg	<3.8	<3	N/A	24	250
Eu-155	SURFACE SOIL	Bq/kg	<7.3	<2.6	N/A	24	250
Fe-59	SURFACE SOIL	Bq/kg	<4.8	<2	N/A	24	333
H-3	SURFACE SOIL	Bq/kg (HTO)	729	249	125.8	24	7.563
I-131	SURFACE SOIL	Bq/kg	<69.9	<2	N/A	24	333
K-40	SURFACE SOIL	Bq/kg	602	329	71.4	24	370
La-140	SURFACE SOIL	Bq/kg	<32.2	<2	N/A	24	333
Mn-54	SURFACE SOIL	Bq/kg	<1.8	<1	N/A	24	498
Nb-94	SURFACE SOIL	Bq/kg	<1.5	<1	N/A	24	406
Nb-95	SURFACE SOIL	Bq/kg	<2.7	<1	N/A	24	498
Ru-103	SURFACE SOIL	Bq/kg	<2.6	<1	N/A	24	333
Ru-106	SURFACE SOIL	Bq/kg	<14.3	<10	N/A	24	406
Sb-124	SURFACE SOIL	Bq/kg	<3.6	<2	N/A	24	406
Sb-125	SURFACE SOIL	Bq/kg	<4.9	<2	N/A	24	250
Se-75	SURFACE SOIL	Bq/kg	<2.8	<1	N/A	24	287.5
Th-series	SURFACE SOIL	Bq/kg	65.1	8.7	10.8	24	498
U-series	SURFACE SOIL	Bq/kg	48.7	14.8	7.8	24	333
Zn-65	SURFACE SOIL	Bq/kg	<13.2	<3	N/A	24	325
Zr-95	SURFACE SOIL	Bq/kg	<3.6	<2	N/A	24	406
Ag-110m	VEGETATION	Bq/kg	<2.5	<2	N/A	24	NR
Ba-140	VEGETATION	Bq/kg	<303	<6	N/A	24	NR
Be-7	VEGETATION	Bq/kg	32.6	<10	4.8	24	NR

Parameter	Medium	Units	Concentration			# of samples taken	Mass of max sample* (g)
			Maximum	Minimum	Standard Deviation		
C-14	VEGETATION	Bq/kg-C	436	262.00	81.3	24	NR
Ce-141	VEGETATION	Bq/kg	<12.5	<2	N/A	24	NR
Ce-144	VEGETATION	Bq/kg	<17.9	<5	N/A	24	NR
Co-57	VEGETATION	Bq/kg	<2.2	<1	N/A	24	NR
Co-58	VEGETATION	Bq/kg	<3.9	<1	N/A	24	NR
Co-60	VEGETATION	Bq/kg	<3.5	<1	N/A	24	NR
Cr-51	VEGETATION	Bq/kg	<84.5	<10	N/A	24	NR
Cs-134	VEGETATION	Bq/kg	<2.9	<1	N/A	23	NR
Cs-137	VEGETATION	Bq/kg	<2.5	<1	N/A	24	NR
Eu-154	VEGETATION	Bq/kg	<3.9	<3	N/A	24	NR
Eu-155	VEGETATION	Bq/kg	<7.7	<2	N/A	24	NR
Fe-59	VEGETATION	Bq/kg	<10.9	<2	N/A	24	NR
H-3	VEGETATION	Bq/kg (HTO)	436	243	34.8	24	NR
I-131	VEGETATION	Bq/kg	<463	<3.4	N/A	24	NR
K-40	VEGETATION	Bq/kg	304	119	33.7	24	NR
La-140	VEGETATION	Bq/kg	<64.7	<2	N/A	24	NR
Mn-54	VEGETATION	Bq/kg	<2.7	<1	N/A	24	NR
Nb-94	VEGETATION	Bq/kg	<2.2	<1	N/A	24	NR
Nb-95	VEGETATION	Bq/kg	<4.1	<1	N/A	24	NR
Ru-103	VEGETATION	Bq/kg	<6.3	<1	N/A	24	NR
Ru-106	VEGETATION	Bq/kg	<24.1	<10	N/A	24	NR
Sb-124	VEGETATION	Bq/kg	<6.8	<2	N/A	24	NR
Sb-125	VEGETATION	Bq/kg	<6.6	<2	N/A	24	NR
Se-75	VEGETATION	Bq/kg	<4.4	<1	N/A	24	NR
Th-series	VEGETATION	Bq/kg	<7.1	<3	N/A	24	NR
U-series	VEGETATION	Bq/kg	<4.7	<3	N/A	24	NR
Zn-65	VEGETATION	Bq/kg	<5.9	<3	N/A	24	NR
Zr-95	VEGETATION	Bq/kg	<7.6	<2	N/A	24	NR

N/A - Not applicable

NR - Not required

*Sample mass used to convert concentrations from Bq/kg to Bq/m^2

Parameter	Medium	Units	Concentration			# of samples taken	Mass of max sample* (g)
			Maximum	Minimum	Standard Deviation		
Ag-110m	CEDAR	Bq/kg	<2.3	<2	N/A	24	NR
Ba-140	CEDAR	Bq/kg	<14.6	<5	N/A	24	NR
Be-7	CEDAR	Bq/kg	67.9	23.7	12.4	24	NR
C-14	CEDAR	Bq/kg-C	780	370	160.3	24	NR
Ce-141	CEDAR	Bq/kg	<8.4	<1	N/A	24	NR
Ce-144	CEDAR	Bq/kg	<26.2	<5	N/A	24	NR
Co-57	CEDAR	Bq/kg	<3.3	<1	N/A	24	NR
Co-58	CEDAR	Bq/kg	<1.9	<1	N/A	24	NR
Co-60	CEDAR	Bq/kg	<1.4	<1	N/A	24	NR
Cr-51	CEDAR	Bq/kg	<28.6	<10	N/A	24	NR
Cs-134	CEDAR	Bq/kg	<2	<1	N/A	24	NR
Cs-137	CEDAR	Bq/kg	<3.2	<1	N/A	24	NR
Eu-154	CEDAR	Bq/kg	<6.8	<3	N/A	24	NR
Eu-155	CEDAR	Bq/kg	<14.2	<2	N/A	24	NR
Fe-59	CEDAR	Bq/kg	<3	<2	N/A	24	NR
H-3	CEDAR	Bq/kg (HTO)	395	152	74.6	24	NR
I-131	CEDAR	Bq/kg	<4.2	<2	N/A	24	NR
K-40	CEDAR	Bq/kg	103	17.2	21.7	24	NR
La-140	CEDAR	Bq/kg	<2.7	<2	N/A	24	NR
Mn-54	CEDAR	Bq/kg	<1.7	<1	N/A	24	NR
Nb-94	CEDAR	Bq/kg	<1.6	<1	N/A	24	NR
Nb-95	CEDAR	Bq/kg	<2.2	<1	N/A	24	NR
Ru-103	CEDAR	Bq/kg	<3	<1	N/A	24	NR
Ru-106	CEDAR	Bq/kg	<26.8	<10	N/A	24	NR
Sb-124	CEDAR	Bq/kg	<4.7	<2	N/A	24	NR
Sb-125	CEDAR	Bq/kg	<8.6	<2	N/A	24	NR
Se-75	CEDAR	Bq/kg	<4.6	<1	N/A	24	NR
Th-series	CEDAR	Bq/kg	<6.2	<3	N/A	24	NR
U-series	CEDAR	Bq/kg	<6.3	<3	N/A	24	NR
Zn-65	CEDAR	Bq/kg	<3.1	<3	N/A	24	NR
Zr-95	CEDAR	Bq/kg	<3.6	<2	N/A	24	NR
Ag-110m	SOIL AT DEPTH	Bq/kg	<2.4	<2	N/A	24	NR

Parameter	Medium	Units	Concentration			# of samples taken	Mass of max sample* (g)
			Maximum	Minimum	Standard Deviation		
Ba-140	SOIL AT DEPTH	Bq/kg	<23	<5	N/A	24	NR
Be-7	SOIL AT DEPTH	Bq/kg	<14.3	<10	N/A	24	NR
C-14	SOIL AT DEPTH	Bq/kg-C	428	100	96.0	24	0.43117
Ce-141	SOIL AT DEPTH	Bq/kg	<4	<1	N/A	24	NR
Ce-144	SOIL AT DEPTH	Bq/kg	<12.7	<5	N/A	24	NR
Co-57	SOIL AT DEPTH	Bq/kg	<1.6	<1	N/A	24	NR
Co-58	SOIL AT DEPTH	Bq/kg	<1.2	<1	N/A	24	NR
Co-60	SOIL AT DEPTH	Bq/kg	<1	<1	N/A	24	NR
Cr-51	SOIL AT DEPTH	Bq/kg	<21.1	<10	N/A	24	NR
Cs-134	SOIL AT DEPTH	Bq/kg	<1.3	<1	N/A	24	NR
Cs-137	SOIL AT DEPTH	Bq/kg	26.8	<1.2	7.7	24	NR
Eu-154	SOIL AT DEPTH	Bq/kg	<3.2	<3	N/A	24	NR
Eu-155	SOIL AT DEPTH	Bq/kg	<7.5	<2	N/A	24	NR
Fe-59	SOIL AT DEPTH	Bq/kg	<2.7	<2	N/A	24	NR
H-3	SOIL AT DEPTH	Bq/kg (HTO)	419	117	69.4	24	NR
I-131	SOIL AT DEPTH	Bq/kg	<15.9	<2	N/A	24	NR
K-40	SOIL AT DEPTH	Bq/kg	621	258	70.5	24	NR
La-140	SOIL AT DEPTH	Bq/kg	<2.7	<2	N/A	24	NR
Mn-54	SOIL AT DEPTH	Bq/kg	<1.1	<1	N/A	24	NR
Nb-94	SOIL AT DEPTH	Bq/kg	<1	<1	N/A	24	NR
Nb-95	SOIL AT DEPTH	Bq/kg	<1.5	<1	N/A	24	NR
Ru-103	SOIL AT DEPTH	Bq/kg	<1.7	<1	N/A	24	NR
Ru-106	SOIL AT DEPTH	Bq/kg	<10	<10	N/A	24	NR
Sb-124	SOIL AT DEPTH	Bq/kg	<2	<2	N/A	24	NR
Sb-125	SOIL AT DEPTH	Bq/kg	<4	<2	N/A	24	NR
Se-75	SOIL AT DEPTH	Bq/kg	<2.2	<1	N/A	24	NR
Th-series	SOIL AT DEPTH	Bq/kg	29.7	5.5	4.6	24	NR
U-series	SOIL AT DEPTH	Bq/kg	44.1	9.6	8.6	24	NR
Zn-65	SOIL AT DEPTH	Bq/kg	<3	<3	N/A	24	NR
Zr-95	SOIL AT DEPTH	Bq/kg	<2	<2	N/A	24	NR
Ag-110m	SURFACE SOIL	Bq/kg	<18.1	<2	N/A	24	402
Ba-140	SURFACE SOIL	Bq/kg	<26.8	<5	N/A	24	302

Parameter	Medium	Units	Concentration			# of samples taken	Mass of max sample* (g)
			Maximum	Minimum	Standard Deviation		
Be-7	SURFACE SOIL	Bq/kg	<18.2	<10	N/A	24	302
C-14	SURFACE SOIL	Bq/kg-C	460	118	102.8	24	0.464667
Ce-141	SURFACE SOIL	Bq/kg	<4.8	<1.2	N/A	24	336
Ce-144	SURFACE SOIL	Bq/kg	<13.1	<5	N/A	24	270
Co-57	SURFACE SOIL	Bq/kg	<1.7	<1	N/A	24	270
Co-58	SURFACE SOIL	Bq/kg	<1.3	<1	N/A	24	270
Co-60	SURFACE SOIL	Bq/kg	1.8	<1	N/A	24	588
Cr-51	SURFACE SOIL	Bq/kg	<26.8	<10	N/A	24	336
Cs-134	SURFACE SOIL	Bq/kg	<1.5	<1	N/A	24	339
Cs-137	SURFACE SOIL	Bq/kg	37.2	3.7	12.1	24	329
Eu-154	SURFACE SOIL	Bq/kg	<3.3	<3	N/A	24	270
Eu-155	SURFACE SOIL	Bq/kg	<6.5	<2	N/A	24	270
Fe-59	SURFACE SOIL	Bq/kg	<2.8	<2	N/A	24	270
H-3	SURFACE SOIL	Bq/kg (HTO)	391	124	70.4	24	7.37
I-131	SURFACE SOIL	Bq/kg	<17.2	<2	N/A	24	357
K-40	SURFACE SOIL	Bq/kg	561	239	75.9	24	402
La-140	SURFACE SOIL	Bq/kg	<4.6	<2	N/A	24	336
Mn-54	SURFACE SOIL	Bq/kg	<1.1	<1	N/A	24	270
Nb-94	SURFACE SOIL	Bq/kg	<1.1	<1	N/A	24	270
Nb-95	SURFACE SOIL	Bq/kg	<2.4	<1	N/A	24	402
Ru-103	SURFACE SOIL	Bq/kg	<2.4	<1	N/A	24	302
Ru-106	SURFACE SOIL	Bq/kg	<13.3	<10	N/A	24	302
Sb-124	SURFACE SOIL	Bq/kg	<2	<2	N/A	24	424.5
Sb-125	SURFACE SOIL	Bq/kg	<4.8	<2	N/A	24	302
Se-75	SURFACE SOIL	Bq/kg	<2.6	<1	N/A	24	270
Th-series	SURFACE SOIL	Bq/kg	26.2	7.6	4.7	24	402
U-series	SURFACE SOIL	Bq/kg	58.5	12.1	14.7	24	302
Zn-65	SURFACE SOIL	Bq/kg	<3	<3	N/A	24	424.5
Zr-95	SURFACE SOIL	Bq/kg	<2.3	<2	N/A	24	329
Ag-110m	VEGETATION	Bq/kg	<2.7	<2	N/A	24	NR
Ba-140	VEGETATION	Bq/kg	<23.4	<6.7	N/A	24	NR
Be-7	VEGETATION	Bq/kg	96.4	11	24.1	24	NR

Parameter	Medium	Units	Concentration			# of samples taken	Mass of max sample* (g)
			Maximum	Minimum	Standard Deviation		
C-14	VEGETATION	Bq/kg-C	702	358	118.5	24	NR
Ce-141	VEGETATION	Bq/kg	<10.9	<1.5	N/A	24	NR
Ce-144	VEGETATION	Bq/kg	<38.4	<6.2	N/A	24	NR
Co-57	VEGETATION	Bq/kg	<5.2	<1	N/A	24	NR
Co-58	VEGETATION	Bq/kg	<3	<1	N/A	24	NR
Co-60	VEGETATION	Bq/kg	5.6	<1	N/A	24	NR
Cr-51	VEGETATION	Bq/kg	<52.4	<10	N/A	24	NR
Cs-134	VEGETATION	Bq/kg	<2.9	<1	N/A	24	NR
Cs-137	VEGETATION	Bq/kg	<3.3	<1	N/A	24	NR
Eu-154	VEGETATION	Bq/kg	<10.7	<3	N/A	24	NR
Eu-155	VEGETATION	Bq/kg	<21.5	<4	N/A	24	NR
Fe-59	VEGETATION	Bq/kg	<5.9	<2	N/A	24	NR
H-3	VEGETATION	Bq/kg (HTO)	351	95.5	90.8	24	NR
I-131	VEGETATION	Bq/kg	<12.4	<2	N/A	24	NR
K-40	VEGETATION	Bq/kg	371	78.6	72.7	24	NR
La-140	VEGETATION	Bq/kg	<5	<2	N/A	24	NR
Mn-54	VEGETATION	Bq/kg	<2.9	<1	N/A	24	NR
Nb-94	VEGETATION	Bq/kg	<2.6	<1	N/A	24	NR
Nb-95	VEGETATION	Bq/kg	<3.1	<1	N/A	24	NR
Ru-103	VEGETATION	Bq/kg	<4.8	<1.2	N/A	24	NR
Ru-106	VEGETATION	Bq/kg	<28.1	<10	N/A	24	NR
Sb-124	VEGETATION	Bq/kg	<4.5	<2	N/A	24	NR
Sb-125	VEGETATION	Bq/kg	<12.1	<2.8	N/A	24	NR
Se-75	VEGETATION	Bq/kg	<6.9	<1.4	N/A	24	NR
Th-series	VEGETATION	Bq/kg	<8.4	<3	N/A	24	NR
U-series	VEGETATION	Bq/kg	<5.7	<2.4	N/A	24	NR
Zn-65	VEGETATION	Bq/kg	<5.2	<3	N/A	24	NR
Zr-95	VEGETATION	Bq/kg	<4.4	<2	N/A	24	NR

N/A - Not applicable

NR - Not required

*Sample mass used to convert concentrations from Bq/kg to Bq/m^2

Parameter	Medium	Units	Concentration			# of samples taken (excl.	Mass of max sample* (g)
			Maximum	Minimum	Standard Deviation		
Ag-110m	CEDAR	Bq/kg	<2	<2	N/A	24	NR
Ba-140	CEDAR	Bq/kg	<17.7	<5	N/A	24	NR
Be-7	CEDAR	Bq/kg	111	17.6	24.69	24	NR
C-14	CEDAR	Bq/kg-C	833	350	141.04	24	NR
Ce-141	CEDAR	Bq/kg	<5.5	<1	N/A	24	NR
Ce-144	CEDAR	Bq/kg	<20.5	<5	N/A	24	NR
Co-57	CEDAR	Bq/kg	<2.6	<1	N/A	21	NR
Co-58	CEDAR	Bq/kg	<1.6	<1	N/A	21	NR
Co-60	CEDAR	Bq/kg	<1.4	<0.7	N/A	24	NR
Cr-51	CEDAR	Bq/kg	<28	<10	N/A	24	NR
Cs-134	CEDAR	Bq/kg	<1.7	<1	N/A	24	NR
Cs-137	CEDAR	Bq/kg	<1.6	<0.7	N/A	24	NR
Eu-154	CEDAR	Bq/kg	<5.4	<3	N/A	24	NR
Eu-155	CEDAR	Bq/kg	<11	<2	N/A	24	NR
Fe-59	CEDAR	Bq/kg	<2.5	<2	N/A	24	NR
H-3	CEDAR	Bq/kg (HTO)	538	201	114.19	24	NR
I-131	CEDAR	Bq/kg	<8.1	<2	N/A	24	NR
K-40	CEDAR	Bq/kg	116	44.4	18.31	24	NR
La-140	CEDAR	Bq/kg	<2.3	<2	N/A	24	NR
Mn-54	CEDAR	Bq/kg	<1.4	<1	N/A	24	NR
Nb-94	CEDAR	Bq/kg	<1.3	<1	N/A	24	NR
Nb-95	CEDAR	Bq/kg	<1.6	<1	N/A	24	NR
Ru-103	CEDAR	Bq/kg	<2.9	<1	N/A	24	NR
Ru-106	CEDAR	Bq/kg	<20.4	<10	N/A	24	NR
Sb-124	CEDAR	Bq/kg	<2.7	<2	N/A	24	NR
Sb-125	CEDAR	Bq/kg	<7.3	<2	N/A	24	NR
Se-75	CEDAR	Bq/kg	<4	<1	N/A	24	NR
Th-series	CEDAR	Bq/kg	<4.4	<3	N/A	24	NR
U-series	CEDAR	Bq/kg	3.5	<3	N/A	24	NR
Zn-65	CEDAR	Bq/kg	<3.1	<3	N/A	24	NR
Zr-95	CEDAR	Bq/kg	<2.5	<2	N/A	24	NR
Ag-110m	VEGETATION	Bq/kg	<2.3	<2	N/A	24	NR

Parameter	Medium	Units	Concentration			# of samples taken (excl.	Mass of max sample* (g)
			Maximum	Minimum	Standard Deviation		
Ba-140	VEGETATION	Bq/kg	<29.7	<5.1	N/A	24	NR
Be-7	VEGETATION	Bq/kg	195	51.8	32.0	24	NR
C-14	VEGETATION	Bq/kg-C	833	350	124.27	24	NR
Ce-141	VEGETATION	Bq/kg	<9.9	<1	N/A	24	NR
Ce-144	VEGETATION	Bq/kg	<32.2	<5	N/A	24	NR
Co-57	VEGETATION	Bq/kg	<4.1	<1	N/A	24	NR
Co-58	VEGETATION	Bq/kg	<2.4	<1	N/A	24	NR
Co-60	VEGETATION	Bq/kg	<1.9	<1	N/A	24	NR
Cr-51	VEGETATION	Bq/kg	<50	<10	N/A	24	NR
Cs-134	VEGETATION	Bq/kg	<2.4	<1	N/A	24	NR
Cs-137	VEGETATION	Bq/kg	<2.5	<1	N/A	24	NR
Eu-154	VEGETATION	Bq/kg	<8.3	<3	N/A	24	NR
Eu-155	VEGETATION	Bq/kg	<16.6	<2	N/A	24	NR
Fe-59	VEGETATION	Bq/kg	<4.6	<2	N/A	24	NR
H-3	VEGETATION	Bq/kg (HTO)	921	361	125.75	24	NR
I-131	VEGETATION	Bq/kg	<17.8	<2	N/A	24	NR
K-40	VEGETATION	Bq/kg	246	92.8	36.2	24	NR
La-140	VEGETATION	Bq/kg	<4.2	<2	N/A	24	NR
Mn-54	VEGETATION	Bq/kg	<2.1	<1	N/A	24	NR
Nb-94	VEGETATION	Bq/kg	<2	<1	N/A	24	NR
Nb-95	VEGETATION	Bq/kg	<2.6	<1	N/A	24	NR
Ru-103	VEGETATION	Bq/kg	<4	<1	N/A	24	NR
Ru-106	VEGETATION	Bq/kg	<27.2	<10	N/A	24	NR
Sb-124	VEGETATION	Bq/kg	<3.1	<2	N/A	24	NR
Sb-125	VEGETATION	Bq/kg	<10.2	<2	N/A	24	NR
Se-75	VEGETATION	Bq/kg	<5.9	<1	N/A	24	NR
Th-series	VEGETATION	Bq/kg	3.1	<3	N/A	24	NR
U-series	VEGETATION	Bq/kg	3.5	<3	N/A	24	NR
Zn-65	VEGETATION	Bq/kg	<4.2	<3	N/A	24	NR
Zr-95	VEGETATION	Bq/kg	<4.2	<2	N/A	24	NR

N/A - Not applicable

NR - Not required

*Sample mass used to convert concentrations from Bq/kg to Bq/m^2

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Volatile Organics						
Acetone	µg/L	10	<10	<10	N/A	27
Benzene	µg/L	0.2	<0.2	<0.2	N/A	27
Bromodichloromethane	µg/L	0.5	<0.5	<0.5	N/A	27
Bromoform	µg/L	1	<1	<1	N/A	27
Bromomethane	µg/L	0.5	<0.5	<0.5	N/A	27
Carbon Tetrachloride	µg/L	0.2	<0.2	<0.2	N/A	27
Chlorobenzene	µg/L	0.2	<0.2	<0.2	N/A	27
Chloroform	µg/L	0.2	<0.2	<0.2	N/A	27
Dibromochloromethane	µg/L	0.5	<0.5	<0.5	N/A	27
1,2-Dichlorobenzene	µg/L	0.5	<0.5	<0.5	N/A	27
1,3-Dichlorobenzene	µg/L	0.5	<0.5	<0.5	N/A	27
1,4-Dichlorobenzene	µg/L	0.5	<0.5	<0.5	N/A	27
1,1-Dichloroethane	µg/L	0.2	<0.2	<0.2	N/A	27
1,2-Dichloroethane	µg/L	0.5	<0.5	<0.5	N/A	27
1,1-Dichloroethylene	µg/L	0.2	<0.2	<0.2	N/A	27
Cis-1,2-Dichloroethylene	µg/L	0.5	<0.5	<0.5	N/A	27
Trans-1,2-Dichloroethylene	µg/L	0.5	<0.5	<0.5	N/A	27
1,2-Dichloropropane	µg/L	0.2	<0.2	<0.2	N/A	27
Cis-1,3-Dichloropropylene	µg/L	0.3	<0.3	<0.3	N/A	27
Trans-1,3-Dichloropropylene	µg/L	0.4	<0.4	<0.4	N/A	27
Ethylbenzene	µg/L	0.2	<0.2	<0.2	N/A	27
Ethylene Dibromide	µg/L	0.2	<0.2	<0.2	N/A	27
Methyl Ethyl Ketone	µg/L	10	<10	<10	N/A	27
Methylene Chloride	µg/L	2	<2	<2	N/A	27
Methyl Isobutyl Ketone	µg/L	5	<5	<5	N/A	27
Methyl-t-Butyl Ether	µg/L	0.5	<0.5	<0.5	N/A	27
Styrene	µg/L	0.5	<0.5	<0.5	N/A	27
1,1,1,2-Tetrachloroethane	µg/L	0.5	<0.5	<0.5	N/A	27
1,1,2,2-Tetrachloroethane	µg/L	0.5	<0.5	<0.5	N/A	27
Toluene	µg/L	0.2	<0.2	<0.2	N/A	27
Tetrachloroethylene	µg/L	0.2	<0.2	<0.2	N/A	27

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
1,1,1-Trichloroethane	µg/L	0.2	<0.2	<0.2	N/A	27
1,1,2-Trichloroethane	µg/L	0.5	<0.5	<0.5	N/A	27
Trichloroethylene	µg/L	0.2	<0.2	<0.2	N/A	27
Vinyl Chloride	µg/L	0.2	<0.2	<0.2	N/A	27
m-Xylene & p-Xylene	µg/L	0.2	<0.2	<0.2	N/A	27
o-Xylene	µg/L	0.2	<0.2	<0.2	N/A	27
Total Xylenes	µg/L	0.2	<0.2	<0.2	N/A	27
Dichlorodifluoromethane	µg/L	1	<1	<1	N/A	27
Hexane(n)	µg/L	1	<2	<2	N/A	27
Trichlorofluoromethane	µg/L	0.5	<0.5	<0.5	N/A	27
PHCs						
Benzene	µg/L	0.2	<0.2	<0.2	N/A	14
Toluene	µg/L	0.2	0.24	<0.2	N/A	14
Ethylbenzene	µg/L	0.2	<0.2	<0.2	N/A	14
m/p xylenes	µg/L	0.4	<0.4	<0.4	N/A	14
o xylene	µg/L	0.2	<0.2	<0.2	N/A	14
Total Xylenes	µg/L	0.4	<0.4	<0.4	N/A	14
PHC F1 (C6-C10)	µg/L	25	<25	<25	N/A	27
PHC F1 (C6-C10) - BTEX	µg/L	25	<25	<25	N/A	27
PHC F2 (C10-C16)	µg/L	100	<100	<100	N/A	27
PHC F3 (C16-C34)	µg/L	200	<200	<200	N/A	27
PHC F4 (C34-C50)	µg/L	200	<200	<200	N/A	27
Reached Baseline at C50	µg/L	N/A	YES	YES	N/A	27
Calculated Parameters						
Hardness (CaCO3)	mg/L	1	850	200	210.23	27
Inorganics						
Chromium VI	µg/L	0.5	<0.5	<0.5	N/A	27
Cyanide, Free	µg/L	2	<2	<2	N/A	27

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Conductivity	umho/cm	1	1600	460	360.75	27
Total Dissolved Solids	mg/L	10	1340	204	331.22	27
Fluoride (F-)	mg/L	0.1	2.1	0.74	0.52	27
Orthophosphate (P)	mg/L	0.01	0.62	<0.01	0.26	27
pH	pH		8.25	7.51	0.17	27
Dissolved Sulphate (SO4)	mg/L	1	820	7	262.68	27
Alkalinity (Total as CaCO3)	mg/L	1	320	58	81.94	27
Nitrite	mg/L	0.01	0.027	<0.01	0.01	27
Nitrate	mg/L	0.1	<0.1	<0.1	N/A	27
Dissolved Bromide (Br-)	mg/L	1	<1	<1	N/A	27
Chloride	mg/L	1	100	<1	35.17	27
Metals						
Antimony	µg/L	0.5	1.2	<0.5	0.275	27
Arsenic	µg/L	1	11	<1	3.172	27
Barium	µg/L	2	2200	7.4	746.848	27
Beryllium	µg/L	0.5	<0.5	<0.5	N/A	27
Boron	µg/L	10	360	13	97.904	27
Cadmium	µg/L	0.1	<0.1	<0.1	N/A	27
Chromium	µg/L	5	<5	<5	N/A	27
Cobalt	µg/L	0.5	<0.5	<0.5	N/A	27
Copper	µg/L	1	1.6	<1	0.250	27
Lead	µg/L	0.5	<0.5	<0.5	N/A	27
Mercury	µg/L	0.1	<0.1	<0.1	N/A	27
Molybdenum	µg/L	0.5	6.2	1.4	1.502	27
Nickel	µg/L	1	3.8	<1	0.287	27
Sodium	µg/L	100	58000	12000	16749.424	27
Selenium	µg/L	2	<2	<2	N/A	27
Silver	µg/L	0.1	<0.1	<0.1	N/A	27
Thallium	µg/L	0.05	0.069	<0.05	0.007	27
Vanadium	µg/L	0.5	1.2	<0.5	0.195	27
Zinc	µg/L	5	21	<5	7.000	27

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Uranium	µg/L	0.1	6.6	<0.1	2.010	27

RDL - Reportable Detection Limit.

N/A - Not applicable

PHC - petroleum hydrocarbons. "F" means fraction.

< - not detected above the reportable detection limit as shown.

Parameter	Units	MDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
PHCs						
PHC F1 (C6-C10 less BTEX)	µg/g dw	10	<10	<10	N/A	12
PHC F2 (>C10-C16)	µg/g dw	10	68	<10	18.86	24
PHC F3 (>C16-C34)	µg/g dw	50	170	<50	34.44	24
PHC F4 (>C34)^	µg/g dw	50	520	<50	155.47	24
Inorganics						
Antimony	µg/g dw	0.2	0.57	<0.2	0.10	12
Arsenic	µg/g dw	1	7	1.4	1.86	12
Barium	µg/g dw	0.5	71	7.9	19.80	12
Beryllium	µg/g dw	0.2	0.63	<0.2	0.14	12
Boron (Hot Water Soluble)	µg/g dw	0.05	1.1	0.1	0.28	12
Cadmium	µg/g dw	0.1	0.9	<0.1	0.25	12
Chromium	µg/g dw	1	22	5.8	4.83	12
Chromium VI	µg/g dw	0.2	<0.2	<0.2	N/A	12
Cobalt	µg/g dw	0.1	9.1	1.5	2.12	12
Copper	µg/g dw	0.5	31	7.6	5.91	12
Lead	µg/g dw	1	23	4.2	6.29	12
Manganese	µg/g dw	0.20	1300	180	310.73	12
Mercury	µg/g dw	0.05	0.12	<0.05	N/A	12
Molybdenum	µg/g dw	0.5	1	<0.5	0.16	12
Nickel	µg/g dw	0.5	19	6.4	3.68	12
Selenium	µg/g dw	0.5	0.84	<0.5	0.14	12
Silver	µg/g dw	0.2	<0.2	<0.2	N/A	12
Thallium	µg/g dw	0.05	0.2	<0.05	0.05	12
Vanadium	µg/g dw	5	44	8.1	10.92	12
Zinc	µg/g dw	5	140	20	36.17	12
pH (pH Units)	µg/g dw	NV	7.94	7.03	0.27	12
Conductivity (ms/cm)	µg/g dw	0.002	0.42	0.12	0.08	12
Sodium Adsorption Ratio	µg/g dw	NV	3.7	0.19	0.97	12
Boron (Total)	µg/g dw	5	14	6.5	2.30	12
Uranium	µg/g dw	0.05	0.97	0.35	0.17	12

Parameter	Units	MDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Volatile Organics						
Acetone	µg/g dw	0.5	<1.0	<0.5	N/A	12
Benzene	µg/g dw	0.006	<0.012	<0.006	N/A	12
Bromodichloromethane	µg/g dw	0.05	<0.1	<0.05	N/A	12
Bromoform	µg/g dw	0.05	<0.1	<0.05	N/A	12
Bromomethane	µg/g dw	0.05	<0.1	<0.05	N/A	12
Carbon Tetrachloride	µg/g dw	0.05	<0.1	<0.05	N/A	12
Chlorobenzene	µg/g dw	0.05	<0.1	<0.05	N/A	12
Chloroform	µg/g dw	0.05	<0.1	<0.05	N/A	12
Dibromochloromethane	µg/g dw	0.05	<0.1	<0.05	N/A	12
1,2-Dichlorobenzene	µg/g dw	0.05	<0.1	<0.05	N/A	12
1,3-Dichlorobenzene	µg/g dw	0.05	<0.1	<0.05	N/A	12
1,4-Dichlorobenzene	µg/g dw	0.05	<0.1	<0.05	N/A	12
1,1-Dichloroethane	µg/g dw	0.05	<0.1	<0.05	N/A	12
1,2-Dichloroethane	µg/g dw	0.05	<0.1	<0.05	N/A	12
1,1-Dichloroethylene	µg/g dw	0.05	<0.1	<0.05	N/A	12
Cis-1,2-Dichloroethylene	µg/g dw	0.05	<0.1	<0.05	N/A	12
Trans-1,2-Dichloroethylene	µg/g dw	0.05	<0.1	<0.05	N/A	12
1,2-Dichloropropane	µg/g dw	0.05	<0.1	<0.05	N/A	12
Cis-1,3-Dichloropropylene	µg/g dw	0.03	<0.06	<0.03	N/A	12
Trans-1,3-Dichloropropylene	µg/g dw	0.04	<0.08	<0.04	N/A	12
Ethylbenzene	µg/g dw	0.01	<0.02	<0.01	N/A	12
Ethylene Dibromide	µg/g dw	0.05	<0.1	<0.05	N/A	12
Methyl Ethyl Ketone	µg/g dw	0.5	<1.0	<0.5	N/A	12
Methylene Chloride	µg/g dw	0.05	<0.1	<0.05	N/A	12
Methyl Isobutyl Ketone	µg/g dw	0.5	<1.0	<0.5	N/A	12
Methyl-t-Butyl Ether	µg/g dw	0.05	<0.1	<0.05	N/A	12
Styrene	µg/g dw	0.05	<0.1	<0.05	N/A	12
1,1,1,2-Tetrachloroethane	µg/g dw	0.05	<0.1	<0.05	N/A	12
1,1,2,2-Tetrachloroethane	µg/g dw	0.05	<0.1	<0.05	N/A	12
Toluene	µg/g dw	0.02	<0.04	<0.02	N/A	12

Parameter	Units	MDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Tetrachloroethylene	µg/g dw	0.05	<0.1	<0.05	N/A	12
1,1,1-Trichloroethane	µg/g dw	0.05	<0.1	<0.05	N/A	12
1,1,2-Trichloroethane	µg/g dw	0.05	<0.1	<0.05	N/A	12
Trichloroethylene	µg/g dw	0.01	<0.02	<0.01	N/A	12
Vinyl Chloride	µg/g dw	0.02	<0.04	<0.02	N/A	12
m-Xylene & p-Xylene	µg/g dw	0.02	<0.04	<0.02	N/A	12
o-Xylene	µg/g dw	0.02	<0.04	<0.02	N/A	12
Total Xylenes	µg/g dw	0.02	<0.04	<0.02	N/A	12
Dichlorodifluoromethane	µg/g dw	0.05	<0.1	<0.05	N/A	12
Hexane(n)	µg/g dw	0.05	<0.1	<0.05	N/A	12
Trichlorofluoromethane	µg/g dw	0.05	<0.1	<0.05	N/A	12
Dioxins		**WHO (2005) TEF**				
2,3,7,8-Tetra CDD *	pg/g	1	1.17	<0.101	0.42	23
1,2,3,7,8-Penta CDD	pg/g	1	5.61	<0.0966	1.57	23
1,2,3,4,7,8-Hexa CDD	pg/g	0.1	11.1	<0.0961	3.37	23
1,2,3,6,7,8-Hexa CDD	pg/g	0.1	19.6	<0.0962	5.28	23
1,2,3,7,8,9-Hexa CDD	pg/g	0.1	30.4	<0.0853	6.68	23
1,2,3,4,6,7,8-Hepta CDD	pg/g	0.01	586	1.09	153.53	23
Octa CDD	pg/g	0.0003	3060	7.78	792.43	23
Total Tetra CDD	pg/g		10.4	<0.104	2.97	12
Total Penta CDD	pg/g		60.7	<0.106	16.45	12
Total Hexa CDD	pg/g		593	0.15	160.57	12
Total Hepta CDD	pg/g		1640	1.09	444.42	12
Furans						
2,3,7,8-Tetra CDF **	pg/g	0.1	2.75	<0.0964	0.79	23
1,2,3,7,8-Penta CDF	pg/g	0.03	2.27	<0.104	0.59	23
2,3,4,7,8-Penta CDF	pg/g	0.3	4	<0.105	0.96	23
1,2,3,4,7,8-Hexa CDF	pg/g	0.1	18.1	<0.104	4.34	23
1,2,3,6,7,8-Hexa CDF	pg/g	0.1	7.24	<0.0913	1.71	23
2,3,4,6,7,8-Hexa CDF	pg/g	0.1	14	<0.106	3.12	23
1,2,3,7,8,9-Hexa CDF	pg/g	0.1	0.737	<0.104	0.18	23

Parameter	Units	MDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
1,2,3,4,6,7,8-Hepta CDF	pg/g	0.01	69.8	<0.561	18.37	23
1,2,3,4,7,8,9-Hepta CDF	pg/g	0.01	16.4	<0.12	3.58	23
Octa CDF	pg/g	0.0003	221	1.16	56.17	23
Total Tetra CDF	pg/g		29	<0.104	8.67	12
Total Penta CDF	pg/g		50.1	<0.105	13.83	12
Total Hexa CDF	pg/g		80.6	0.426	24.15	12
Total Hepta CDF	pg/g		139	0.825	47.65	12
TOTAL TEQ	pg/g		23.3	0.2	5.62	23

MDL - Measurable Detection Limit.

N/A - Not applicable

NV - No Value

PHC - petroleum hydrocarbons. "F" means fraction.

< - not detected above the reportable detection limit as shown.

^If F4 analysis by GC/FID did not reach baseline, F4 gravimetric analysis was conducted. Higher of two F4 values shown.

* CDD indicates Chloro Dibenzo-p-Dioxin

** CDF indicates Chloro Dibenzo-p-Furan

TEQ indicates Toxic Equivalency Quotient

WHO(2005): The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds

TEF indicates Toxic Equivalency Factor

The TEQ value reported is the sum of the TEQ for the individual congeners (i.e. the WHO (2005) TEF multiplied by the detected congener). If the congener was not detected then half the estimated detection limit was used.

Summary of Surface Water Baseline Data

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Calculated Parameters						
Hardness (CaCO3)	mg/L	1.0	370	74	95.449	15
Total Unionized Ammonia	mg/L	0.0005	0.017	<0.0005	0.004	15
Field Measurements						
Field Temperature	Celcius	N/A	28.84	1.46	7.344	15
Field pH	pH		8.48	6.99	0.376	15
Inorganics						
Total Ammonia-N	µg/L	0.01	0.56	0.07	0.145	15
Total Chemical Oxygen Demand	µg/L	4.0	33.5	7.5	6.995	15
Conductivity	µS/cm	1.0	2000	400	552.520	15
Total Dissolved Solids	mg/L	10	1060	200	290.907	15
Total Organic Carbon	mg/L	0.20	13.5	2.3	2.833	15
Lab pH	pH		8.335	7.82	0.138	15
Total Phosphorus	mg/L	0.002	0.0155	<0.002	0.005	15
Total Suspended Solids	mg/L	1	5	<1	1.600	15
Alkalinity	mg/L	1.0	340	63.5	86.651	15
Dissolved Chloride (Cl)	mg/L	1-5^	460	41	154.783	15
BTEX & F1 Hydrocarbons						
PHC F1 (C6-C10)	µg/L	25	<25	<25	N/A	15
PHC F1 (C6-C10) - BTEX	µg/L	25	<25	<25	N/A	15
F2-F4 Hydrocarbons						
PHC F2 (C10-C16 Hydrocarbons)	µg/L	100	<100	<100	N/A	15
PHC F3 (C16-C34 Hydrocarbons)	µg/L	200	<200	<200	N/A	15
PHC F4 (C34-C50 Hydrocarbons)	µg/L	200	<200	<200	N/A	15
Volatile Organics						
1,3-Dichloropropene (cis+trans)	µg/L	0.50	<0.5	<0.6	N/A	15
Acetone (2-Propanone)	µg/L	10	<10	<11	N/A	15

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Benzene	µg/L	0.20	<0.2	<0.2	N/A	15
Bromodichloromethane	µg/L	0.50	<0.5	<0.5	N/A	15
Bromoform	µg/L	1.0	<1	<2	N/A	15
Bromomethane	µg/L	0.50	<0.5	<0.5	N/A	15
Carbon Tetrachloride	µg/L	0.20	<0.2	<0.2	N/A	15
Chlorobenzene	µg/L	0.20	<0.2	<0.2	N/A	15
Chloroform	µg/L	0.20	<0.2	<0.2	N/A	15
Dibromochloromethane	µg/L	0.50	<0.5	<0.5	N/A	15
1,2-Dichlorobenzene	µg/L	0.50	<0.5	<0.5	N/A	15
1,3-Dichlorobenzene	µg/L	0.50	<0.5	<0.5	N/A	15
1,4-Dichlorobenzene	µg/L	0.50	<0.5	<0.5	N/A	15
Dichlorodifluoromethane	µg/L	1.0	<1	<2	N/A	15
1,1-Dichloroethane	µg/L	0.20	<0.2	<0.2	N/A	15
1,2-Dichloroethane	µg/L	0.50	<0.5	<0.5	N/A	15
1,1-Dichloroethylene	µg/L	0.20	<0.2	<0.2	N/A	15
cis-1,2-Dichloroethylene	µg/L	0.50	<0.5	<0.5	N/A	15
trans-1,2-Dichloroethylene	µg/L	0.50	<0.5	<0.5	N/A	15
1,2-Dichloropropane	µg/L	0.20	<0.2	<0.2	N/A	15
cis-1,3-Dichloropropene	µg/L	0.30	<0.3	<0.3	N/A	15
trans-1,3-Dichloropropene	µg/L	0.40	<0.4	<0.4	N/A	15
Ethylbenzene	µg/L	0.20	<0.2	<0.2	N/A	15
Ethylene Dibromide	µg/L	0.20	<0.2	<0.2	N/A	15
Hexane	µg/L	1.0	<1	<1	N/A	15
Methylene Chloride	µg/L	2.0	<2	<2	N/A	15
Methyl Isobutyl Ketone	µg/L	5.0	<5	<5	N/A	15
Methyl Ethyl Ketone	µg/L	10	<10	<10	N/A	15
Methyl t-butyl ether	µg/L	0.50	<0.5	<0.5	N/A	15
Styrene	µg/L	0.50	<0.5	<0.5	N/A	15
1,1,1,2-Tetrachloroethane	µg/L	0.50	<0.5	<0.5	N/A	15
1,1,2,2-Tetrachloroethane	µg/L	0.50	<0.5	<0.5	N/A	15
Tetrachloroethylene	µg/L	0.20	<0.2	<0.2	N/A	15
Toluene	µg/L	0.20	<0.2	<0.2	N/A	15

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
1,1,1-Trichloroethane	µg/L	0.20	<0.2	<0.2	N/A	15
1,1,2-Trichloroethane	µg/L	0.50	<0.5	<0.5	N/A	15
Trichloroethylene	µg/L	0.20	<0.2	<0.2	N/A	15
Vinyl Chloride	µg/L	0.20	<0.2	<0.2	N/A	15
p+m-Xylene	µg/L	0.20	<0.2	<0.2	N/A	15
o-Xylene	µg/L	0.20	<0.2	<0.2	N/A	15
Xylene (Total)	µg/L	0.20	<0.2	<0.2	N/A	15
Trichlorofluoromethane	µg/L	0.50	<0.5	<0.5	N/A	15
Metals						
Chromium (+3)*	µg/L	5	<5	<5	N/A	15
Dissolved (0.2u) Aluminum (Al)	µg/L	5	24	<5	6.944	15
Chromium (VI)*	µg/L	0.50	<0.5	<0.5	N/A	15
Total Mercury - low level (Hg)	µg/L	0.01	0.02	<0.01	N/A	15
Dissolved Mercury (Hg)	µg/L	0.01	0.01	<0.01	N/A	5
Dissolved Calcium (Ca)	µg/L	200	100000	22000	26696.733	15
Dissolved Chromium (Cr)	µg/L	5.0	<5	<5	N/A	15
Dissolved Magnesium (Mg)	µg/L	50	32000	4500	7728.516	15
Total Aluminum (Al)	µg/L	0.5-2.5^	130	2.925	36.688	15
Total Antimony (Sb)	µg/L	0.02-0.10^	0.678	0.058	0.165	15
Total Arsenic (As)	µg/L	0.02-0.11^	0.6015	0.155	0.119	15
Total Barium (Ba)	µg/L	0.02-0.12^	50.5	5.485	13.875	15
Total Beryllium (Be)	µg/L	0.01-0.050^	<0.01	<0.05	N/A	15
Total Bismuth (Bi)	µg/L	0.005-0.025^	<0.025	<0.005	N/A	15
Total Boron (B)	µg/L	50-250^	66.5	<20	15.515	15
Total Cadmium (Cd)	µg/L	0.005-0.025^	0.016	<0.025	0.004	15
Total Calcium (Ca)	mg/L	0.050	92.45	30.2	23.469	5
Total Cesium (Cs)	µg/L	0.05-0.25^	<0.25	<0.25	N/A	15
Total Chromium (Cr)	µg/L	0.1-0.50^	0.99	<0.5	0.266	15
Total Cobalt (Co)	µg/L	0.005-0.025^	0.156	0.027	0.033	15
Total Copper (Cu)	µg/L	0.05-0.25^	1.49	0.253	0.342	15
Total Iron (Fe)	µg/L	1.0-5.0^	635	24.2	167.215	15

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Total Lead (Pb)	µg/L	0.005-0.025^	0.252	0.011	0.059	15
Total Lithium (Li)	µg/L	0.5-2.5^	1.71	0.79	0.300	15
Total Magnesium (Mg)	mg/L	0.050	30.1	6.23	7.870	5
Total Manganese (Mn)	µg/L	0.05-0.25^	65.6	2.41	0.300	15
Total Mercury (Hg)	µg/L	0.01-0.05^	0.01	<0.01	N/A	10
Total Molybdenum (Mo)	µg/L	0.05-0.25^	1.09	0.117	0.280	15
Total Nickel (Ni)	µg/L	0.02-0.10^	1.84	0.364	0.355	15
Total Phosphorus (P)	µg/L	2-10^	14.2	0.5615	5.005	15
Total Selenium (Se)	µg/L	0.04-0.20^	0.2	0.067	0.036	15
Total Silicon (Si)	µg/L	100-500^	4345	199	1167.170	15
Total Silver (Ag)	µg/L	0.005-0.025^	0.005	<0.025	N/A	15
Total Strontium (Sr)	µg/L	0.05-0.25^	3570	262	933.599	15
Total Thallium (Tl)	µg/L	0.002-0.010^	0.012	<0.01	0.004	15
Total Tin (Sn)	µg/L	0.2-1.0^	<1	<0.2	N/A	15
Total Titanium (Ti)	µg/L	0.5-2.5^	6	<0.5	1.961	15
Total Tungsten (W)	µg/L	0.01-0.050^	0.038	<0.01	0.009	15
Total Uranium (U)	µg/L	0.002-0.010^	1.12	0.084	0.356	15
Total Vanadium (V)	µg/L	0.2-1.0^	1.2	<1.0	0.355	15
Total Zinc (Zn)	µg/L	0.1-0.50^	24.1	1.645	6.702	15
Total Zirconium (Zr)	µg/L	0.1-0.50^	0.1	<0.05	N/A	15
Total Sodium (Na)	mg/L	0.05-0.25^	299	35.6	89.073	15
Total Sulphur (S)	mg/L	3-15^	7.15	<3	1.214	15

RDL - Reportable Detection Limit.

N/A - Not applicable

PHC - petroleum hydrocarbons. "F" means fraction.

^indicates multiple RDLs applied by analytical lab.

< - not detected above the reportable detection limit as shown.

*Cr(III) and Cr(VI) to be analyzed at lab only if Total Chromium is detected above 10 ppb.

Parameter	Unit	MDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Aluminum	mg/L	0.0100	0.56133	0.01500	0.16	9
Antimony	mg/L	0.0010	0.0005	<0.0001	0.00017	9
Arsenic	mg/L	0.0010	0.0010	<0.001	0.000014	9
Barium	mg/L	0.0050	0.037	0.010	0.0080	9
Beryllium	mg/L	0.0010	<0.001	<0.0001	N/A	9
Bismuth	mg/L	0.0010	<0.001	<0.0001	N/A	9
Boron	mg/L	0.0001	0.023	0.011	0.0045	9
Cadmium	mg/L	0.0001	<0.0001	<0.0001	N/A	9
Calcium	mg/L	0.0100	95.23	26.33	18.98	9
Cesium	mg/L	0.0001	<0.0001	<0.0001	N/A	9
Chromium	mg/L	0.0001	0.002	<0.0001	0.00081	9
Cobalt	mg/L	0.0001	0.001	0.0001	0.00026	9
Copper	mg/L	0.0001	0.005	0.0009	0.0012	9
Iron	mg/L	0.0050	1.44	0.11	0.42	9
Lead	mg/L	0.0001	0.002	<0.0001	N/A	9
Lithium	mg/L	0.0001	0.003	0.001	0.00068	9
Magnesium	mg/L	0.0020	18.67	4.82	4.02	9
Manganese	mg/L	0.0050	0.32	0.0067	0.12	9
Mercury - low level	mg/L	0.0001	<0.0001	<0.0001	N/A	9
Molybdenum	mg/L	0.0001	0.0007	0.0004	0.00011	9
Nickel	mg/L	0.0001	0.006	0.001	0.0015	9
Phosphorus	mg/L	0.0200	0.29	<0.02	0.09	9
Potassium	mg/L	0.0400	8.61	0.76	2.26	9
Selenium	mg/L	0.0010	0.002	<0.001	0.00047	9
Silicon	mg/L	0.0200	2.42	0.42	0.61	9
Silver	mg/L	0.0001	<0.0001	<0.0001	N/A	9
Sodium	mg/L	0.0500	186.67	17.00	58.52	9
Strontium	mg/L	0.0050	1.67	0.195	0.48	9
Sulphur	mg/L	0.0200	7.73	3.24	1.32	9
Thallium	mg/L	0.0001	<0.0001	<0.0001	N/A	9
Thorium	mg/L	0.0001	0.0001	<0.0001	N/A	9
Tin	mg/L	0.0001	<0.0001	<0.0001	N/A	9

Parameter	Unit	MDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Titanium	mg/L	0.0001	0.0087	0.00057	0.0030	9
Tungsten	mg/L	0.0001	<0.0001	<0.0001	N/A	9
Uranium	mg/L	0.0001	0.0006	0.00013	0.00014	9
Vanadium	mg/L	0.0001	0.001	<0.0001	0.000014	9
Zinc	mg/L	0.0001	0.103	0.0103	0.028	9
Zirconium	mg/L	0.0001	0.00087	<0.0001	0.00028	9

MDL - Measurable Detection Limit.

N/A - Not applicable

< - not detected above the reportable detection limit as shown.

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Physical Properties						
Soluble (2:1) pH	pH		8.20	7.61	0.16	10
Inorganics						
Moisture	%	1	81.50	40.00	16.49	10
Total Organic Carbon	%	0.05	11.00	3.60	2.01	10
Available (CaCl2) pH	pH	N/A	6.97	6.69	0.09	10
BTEX & F1 Hydrocarbons						
PHC F1 (C6-C10)	µg/g	20-100^	<100	<10	N/A	10
PHC F1 (C6-C10) - BTEX	µg/g	20-100^	<100	<10	N/A	10
F2-F4 Hydrocarbons						
F4G-sg (Grav. Heavy Hydrocarbons)	µg/g	100	2300.00	810.00	N/A	2
PHC F2 (C10-C16 Hydrocarbons)	µg/g	10-50^	18.00	<10	N/A	10
PHC F3 (C16-C34 Hydrocarbons)	µg/g	50-250^	1045.00	86.00	295.82	10
PHC F4 (C34-C50 Hydrocarbons)	µg/g	50-250^	380.00	<50	114.77	10
Calculated Parameters						
1,3-Dichloropropene (cis+trans)	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Volatile Organics						
Acetone (2-Propanone)	µg/g	0.5-5.0^	0.51	<0.5	N/A	10
Benzene	µg/g	0.02-0.20^	<0.20	<0.020	N/A	10
Bromodichloromethane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Bromoform	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Bromomethane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Carbon Tetrachloride	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Chlorobenzene	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Chloroform	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Dibromochloromethane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
1,2-Dichlorobenzene	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
1,3-Dichlorobenzene	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
1,4-Dichlorobenzene	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Dichlorodifluoromethane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
1,1-Dichloroethane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
1,2-Dichloroethane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
1,1-Dichloroethylene	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
cis-1,2-Dichloroethylene	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
trans-1,2-Dichloroethylene	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
1,2-Dichloropropane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
cis-1,3-Dichloropropene	µg/g	0.03-0.30^	<0.30	<0.030	N/A	10
trans-1,3-Dichloropropene	µg/g	0.04-0.40^	<0.40	<0.040	N/A	10
Ethylbenzene	µg/g	0.02-0.20^	<0.20	<0.020	N/A	10
Ethylene Dibromide	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Hexane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Methylene Chloride	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Methyl Isobutyl Ketone	µg/g	0.5-5.0^	<5.0	<0.50	N/A	10
Methyl Ethyl Ketone	µg/g	0.5-5.0^	<5.0	<0.50	N/A	10
Methyl t-butyl ether	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Styrene	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
1,1,1,2-Tetrachloroethane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
1,1,2,2-Tetrachloroethane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Tetrachloroethylene	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Toluene	µg/g	0.02-0.20^	<0.20	<0.020	N/A	10
1,1,1-Trichloroethane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
1,1,2-Trichloroethane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Trichloroethylene	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10
Vinyl Chloride	µg/g	0.02-0.20^	<0.20	<0.020	N/A	10
p+m-Xylene	µg/g	0.02-0.20^	<0.20	<0.020	N/A	10
o-Xylene	µg/g	0.02-0.20^	<0.20	<0.020	N/A	10
Xylene (Total)	µg/g	0.02-0.20^	<0.20	<0.020	N/A	10
Trichlorofluoromethane	µg/g	0.05-0.50^	<0.50	<0.050	N/A	10

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Total Metals by ICPMS						
Total Aluminum (Al)	mg/kg	100	12700	4240	3051.49	10
Total Antimony (Sb)	mg/kg	0.1	0.57	0.13	0.11	10
Total Arsenic (As)	mg/kg	0.5	3.20	0.90	0.84	10
Total Barium (Ba)	mg/kg	0.1	90.75	20.60	16.86	10
Total Beryllium (Be)	mg/kg	0.4	0.52	<0.4	0.03	10
Total Bismuth (Bi)	mg/kg	0.1	0.47	<0.1	0.15	10
Total Boron (B)	mg/kg	1	19.60	7.50	3.73	10
Total Cadmium	mg/kg	0.050	0.88	0.23	0.20	10
Total Calcium (Ca)	mg/kg	100	178500	54000	42019.31	10
Total Cesium (Cs)	mg/kg	0.2	0.64	0.30	0.12	10
Total Chromium (Cr)	mg/kg	1	25.10	9.10	4.94	10
Total Cobalt (Co)	mg/kg	0.3	7.13	3.38	1.14	10
Total Copper (Cu)	mg/kg	0.5	156.50	13.50	49.68	10
Total Iron (Fe)	mg/kg	100	17600.00	9300.00	2646.08	10
Total Lead (Pb)	mg/kg	0.1	23.20	5.90	5.39	10
Total Magnesium (Mg)	mg/kg	100	40300.00	17400.00	6571.89	10
Total Manganese (Mn)	mg/kg	0.2	1190.00	282.00	247.92	10
Total Mercury (Hg)	mg/kg	0.05	0.18	<0.05	0.05	10
Total Molybdenum (Mo)	mg/kg	0.1	26.20	0.42	7.53	10
Total Nickel (Ni)	mg/kg	0.8	20.60	7.44	3.55	10
Total Phosphorus (P)	mg/kg	10	787.00	352.00	117.41	10
Total Potassium (K)	mg/kg	100	1870.00	709.50	401.73	10
Total Selenium (Se)	mg/kg	0.5	1.11	<0.5	0.13	10
Total Silver (Ag)	mg/kg	0.05	15.55	0.06	6.28	10
Total Sodium (Na)	mg/kg	100	1490.00	241.00	407.02	10
Total Strontium (Sr)	mg/kg	0.1	1130.00	78.40	349.81	10
Total Thallium (Tl)	mg/kg	0.05	0.22	0.06	0.04	10
Total Tin (Sn)	mg/kg	0.1	1.93	0.26	0.56	10
Total Titanium (Ti)	mg/kg	1	206.00	95.30	41.96	10
Total Tungsten (W)	mg/kg	0.06	0.36	0.07	0.10	10
Total Uranium (U)	mg/kg	0.05	2.23	0.52	0.48	10

Parameter	Units	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Total Vanadium (V)	mg/kg	2	29.65	14.20	4.63	10
Total Zinc (Zn)	mg/kg	1	730.00	57.70	234.28	10
Total Zirconium (Zr)	mg/kg	0.5	3.99	0.89	0.85	10

RDL - Reportable Detection Limit.

N/A - Not applicable

^indicates multiple RDLs applied by analytical lab.

< - not detected above the reportable detection limit as shown.

Parameter	Unit	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Aluminum	mg/kg	1	11800	5547	2193.27	6
Antimony	mg/kg	0.05	0.255	0.058	0.06	6
Arsenic	mg/kg	0.05	7.42	1.95	2.09	6
Barium	mg/kg	0.5	50.2	23.8	8.99	6
Beryllium	mg/kg	0.5	0.764	<0.5	0.18	6
Bismuth	mg/kg	0.05	0.104	<0.05	0.01	6
Boron	mg/kg	0.05	25.47	8.18	6.41	6
Cadmium	mg/kg	0.05	0.393	0.076	0.10	6
Calcium	mg/kg	1	123333	71900	17235.33	6
Cesium	mg/kg	0.05	0.918	0.407	0.17	6
Chromium	mg/kg	1	18.00	8.98	3.08	6
Cobalt	mg/kg	0.05	7.52	3.79	1.24	6
Copper	mg/kg	0.5	17.73	9.97	2.31	6
Iron	mg/kg	0.5	17933	9320	2955.77	6
Lead	mg/kg	0.05	11.67	3.96	2.69	6
Lithium	mg/kg	0.005	15.67	7.87	2.61	6
Magnesium	mg/kg	0.2	36400	31367	1687.28	6
Manganese	mg/kg	0.5	535	332	68.69	6
Mercury	mg/kg	0.05	<0.05	<0.05	N.A	6
Molybdenum	mg/kg	0.05	0.556	0.220	0.12	6
Nickel	mg/kg	1	23.67	7.79	5.89	6
Phosphorus	mg/kg	2	680	364	109.33	6
Potassium	mg/kg	4	2110	1190	300.21	6
Selenium	mg/kg	0.05	0.990	<0.05	0.16	6
Silicon (as Si)	mg/kg	2	688	631	22.02	6
Silver	mg/kg	0.05	0.083	<0.05	0.02	6
Sodium	mg/kg	5	585	225	119.54	6
Strontium	mg/kg	0.5	170	100	23.46	6
Sulphur	mg/kg	2	770	250	177.18	6
Thallium	mg/kg	0.05	0.128	0.068	0.02	6
Thorium	mg/kg	0.05	2.66	1.88	0.26	6
Tin	mg/kg	0.05	0.682	0.287	0.14	6

Parameter	Unit	RDL	Concentration			# of samples taken
			Maximum	Minimum	Standard Deviation	
Titanium	mg/kg	0.5	407	273	43.37	6
Tungsten	mg/kg	0.005	0.113	<0.05	0.02	6
Uranium	mg/kg	0.1	0.712	0.518	0.07	6
Vanadium	mg/kg	2	29.83	14.90	4.95	6
Zinc	mg/kg	0.5	205.33	27.90	62.54	6
Zirconium	mg/kg	0.05	4.74	1.13	1.42	6

RDL - Reportable Detection Limit.

N/A - Not applicable

< - not detected above the reportable detection limit as shown.